臺灣二〇〇七年國際科學展覽會

科　　　　別：化學

作 品 名 稱　：告訴你「拉午耳」「亨利」的壓力有多大
　　　　　　　—自製簡易的 IC 電路板來討論拉午耳及
　　　　　　　亨利定律

得 獎 獎 項　：第一名
　　　　　　　美國團隊正選代表：美國第 58 屆國際科技
　　　　　　　展覽會

學校／作者　：高雄市立高雄女子高級中學　　　陳泱伊
　　　　　　　高雄市立高雄女子高級中學　　　陳映伊

作者簡介

I am Chen Yang Yi, a senior high school student in Kaohsiung Girl's High School. As I learnd more about science, I was more interested in it. And the pleasure that brain storming brings to me makes me more active in trying new things.

As far as I am concerned, participating in the International Science Fair is a chance not only to cultivate the good attitude toward studying but also to make my thinking more logical. At last, I believe the efforts I have paid in this studying will end up be worth it.

我是陳泱伊，來自高雄女中。一直以來，隨著對自然科學的了解愈多，愈是啓發了我對這個領域的興趣，從動腦思考中獲得的樂趣，也讓我更勇於嘗試新鮮事物。這次參加國際科展，經由實驗與探索的過程，不僅讓我培養了正確的實驗態度，科學研究精神與思考方式也更臻純熟。希望研究過程中的努力與成果能在這次比賽中完整地呈現。

作者簡介

I am Chen Ying Yi, a senior high school student in Kaohsiung Girl's High School. As I learnd more about science, I was more interested in it. And

I enjoy thinking, which improve my ability to solve problems and to break through challenges.

As far as I am concerned, participating in the International Science Fair is not only a chance to cultivate the good attitude toward studying but also a chance to make thinking more logical. At last, I believe the efforts I have paid in this studying will end up be worth it.

我是陳映伊，來自高雄女中。一直以來，學習過程中對自然科學的接觸愈多，愈是增進了我對這個領域的興趣，我喜歡在思考和挑戰中突破自己，也培養獨立解決問題的能力。這次參加國際科展，整個研究過程中，不僅讓我培養了正確的實驗態度，科學研究精神與思考方式也更臻純熟。希望這次的努力與成果能在比賽中完整展現。

Abstract :

This research is aimed to make an in-depth exploration into Raoul's Law and Henry's Law by using an accurate but simple vapor pressure gauge. The gauge is constructed from non-complicated electronics components-electronics IC PCB, film resistor, digital multi-meter, and battery.

In the first step, we measured the vapor pressure of six kinds of liquids and 3 liquid mixtures- water, ethanol, chloroform, acetone, benzene, toluene, mixture of water and ethanol, mixture of chloroform and acetone, mixture benzene and toluene. From the results of this experiments, the vapor pressures of water and ethanol liquid mixture, and chloroform and acetone liquid mixture were slightly lower than their theoretic values-called negative deviation solution, while the vapor pressure of the benzene and toluene liquid mixture was quite close to its theoretic value-near an ideal solution.

In the second step, the individual vapor pressures of water, ethanol, and chloroform were measured at various temperatures; the vapor heat(ΔH) were calculated by using the lausius-Clapeyron equation.

In the final step, we used the gauge and other non-commercial instruments to measure the B.O.D. values of water from the Kaohsiung Love River, found the P-T correlation using Gay-Lussac's Law, and calculated the absolute zero temperature value by extrapolation.

壹、中文摘要：

本研究是利用一些簡易的電子元件－電路 IC 板、電阻膜、數位三用電表和電瓶來組裝一個準確、簡易的氣壓量測器。我們將此量測器用來深入探討「拉午耳定律」及「亨利定律」。

首先，我們測量了水、乙醇、氯仿、丙酮、苯、甲苯等六種純液體的蒸氣壓，並測量了(水＋乙醇)、(氯仿＋丙酮)、(苯＋甲苯)等兩成份系溶液的混合蒸氣壓。結果發現(水＋乙醇) 、(氯仿＋丙酮)的混合蒸氣壓都比理論值低了一些，此稱為負偏差溶液；(苯＋甲苯)的混合蒸氣壓與理論值差不多，較接近理想溶液。

接下來，我們還測量了不同溫度下水、酒精及丙酮的蒸氣壓，並利用clausius－clapeyron equation求出液體純質的汽化熱(ΔH)。

最後，我們還搭配了自製的儀器裝置，來測定愛河水質的B.O.D.值(生化需氧量)以及探討氣體的給呂薩克定律(P~T關係)，並利用外差法來推求絕對零度。

貳、研究動機

高中化學課本中涵蓋了許多探討氣體壓力和其相關理論定律的內容，引發我們想著手研究和實際驗證的興趣，但卻發現無法運用簡易可得的裝置以進行氣壓相關的實驗操作，於是我們展開如下的研究,希望設計出以簡易的方法和器材深入探討課本中關於氣體壓力的內容。

由於近年來電子科技蓬勃發展，電子電路廣泛應用於各個領域，有鑑於此以及我們對電子電路進一步探討的興趣，我們希望能了解其原理及應用性，同時尋找適當可行的方法，自製一可精確測量氣壓的簡易 IC 電路板，並進一步將其妥善運用於我們的實驗中。

在課程理論之外，我們的日常生活更與氣體息息相關，仍有許多值得探索的方向，因此我們希望將其應用性與生活結合，並擴展其應用範圍，增進我們對周遭環境的認知與了解。

參、研究目的

一、組裝一可檢測氣體壓力的簡易儀器，並製作其檢量線。

二、驗證拉午耳定律，以及探討不同比例的混合液體之蒸氣壓關係。

三、利用液體純質在不同溫度下的蒸氣壓來推求汽化熱(ΔH)。

四、驗證亨利定律，並探討不同氣體的溶解度與其分壓力之關係。

五、設計簡易方法並搭配自製儀器，來測定愛河水質的 B.O.D. 值。

六、以自製儀器驗證課本理論，並將其應用性擴展至其他氣體壓力定律的測量上。

肆、研究設備及器材

(一)材料				
AB 膠	熱熔膠	錫	銲槍	膠帶
三通閥	針筒（25、60mL）	吸管	細軟管	T 形管
(二)設備				
電阻膜	IC 板	三用電表	鱷魚夾	電瓶(12V)
抽氣機	直流電供應器	恆溫槽	超音波震盪器(除去水中氣體)	
(三)器材				
錐形瓶	寶特瓶	壓克力杯	二氧化碳鋼瓶	氧氣鋼瓶
氮氣鋼瓶	燒杯	溫度計	電子天平（AND HF-400）	
塑膠滴管	塑膠管	保溫杯		
(四)藥品				
蒸餾水	絕對酒精	甲苯	苯	氯仿
丙酮	肥皂水(用以檢驗是否漏氣)			

伍、研究過程及方法

文獻探討：

一、拉午耳定律
  （一）內容：溶液中溶劑之蒸氣壓，等於純溶劑蒸氣壓乘溶劑之莫耳分率。適用於稀薄溶
          液之溶劑計算。

$P_A = x_A \cdot P_A^\circ$ (P_A：溶劑蒸氣壓，P_A°：純溶劑蒸氣壓)
故溶液蒸氣壓 $= P_A + P_B = x_A \cdot P_A^\circ + x_B \cdot P_B^\circ$

  （二）定性討論：
      1.A、B 二液體混合時，若分子間作用力 A－A 與 B－B 等於 A－B，則此混合物
      稱為理想溶液。液體混合時，理想溶液的蒸氣壓符合拉午耳定律。
      2.A、B 二液體混合時，若分子間作用力 A－A 或 B－B 小於 A－B，則此混合液
      稱為非理想負偏差溶液。液體混合時，理想溶液的蒸氣壓實測值小於理論值。
      3.A、B 二液體混合時，若分子間作用力 A－A 或 B－B 大於 A－B，則此混合液
      稱為非理想正偏差溶液。液體混合時，理想溶液的蒸氣壓實測值大於理論值。

（三）理想溶液與非理想溶液之拉午耳定律函數圖

| | | | | | | |
理 想 溶 液　　　　　　對拉午耳定律呈正偏差　　　　　對拉午耳定律呈負偏差
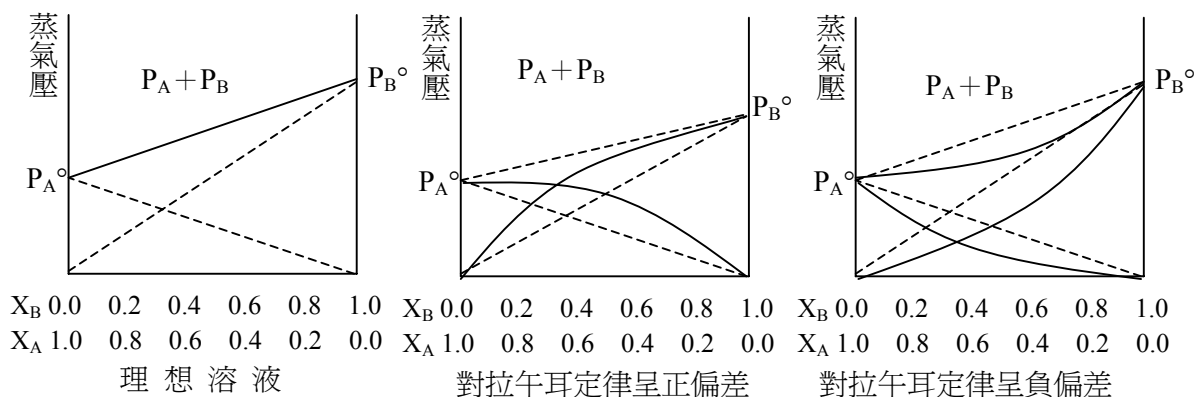
二、亨利定律

　　氣體之溶解度（克數或莫耳數）與其分壓成正比，適用於稀薄溶液之溶質。

　　$m＝kP$，k 為比例常數隨氣體種類及溶劑而異。

三、利用 clausius-clapeyron equation

$$\log P = -\frac{\Delta H}{2.303R}\left(\frac{1}{T}\right) + C \qquad \text{slope} = -\frac{\Delta H}{2.303R}$$

$$\Delta H = 2.303R \times \text{slope} \ \text{cal/mol} = 4.576 \times \text{slope} \ \text{cal/mol}$$

　　實驗中可以找出某特定溫度下的蒸氣壓，再取 $\log P$ 對 $1/T$ 作圖，找出最好的直線，取其斜率為 $-\dfrac{\Delta H_{vap}}{2.303R}$，再求取 $\Delta H_{vap} = -$斜率$\times 2.303R$。

四、將 n、V 一定，找 P～T 關係即給呂薩克定律
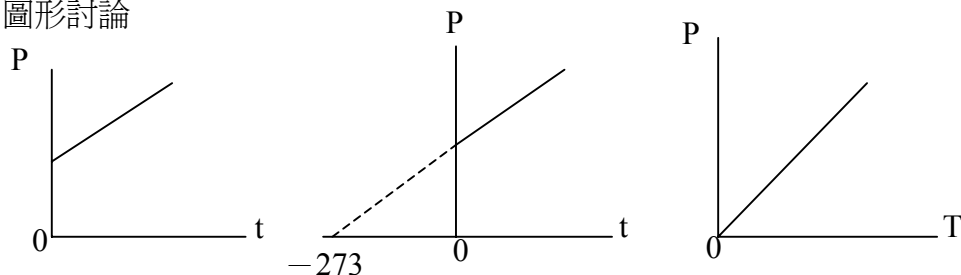
　（一）定量氣體在定容下，每升降 $1°C$，壓力增減 $0°C$ 時壓力的 $\dfrac{1}{273}$

　　　　即 n、V 一定　$P = \dfrac{P_0}{273}t + P_0$

　（二）n、V 一定　$P＝KT$（$T＝273＋t°C$）

　（三）圖形討論

實驗流程：

課本中涵蓋了許多探討氣體壓力定律的內容，於是引發我們想深入研究氣體壓力的測量。

↓

由於電子電路的廣泛應用，在了解其原理及應用性後，我們尋找適當的方法並將其妥善運用於我們的實驗中。

↓

實驗一：利用電子元件—電路 IC 板、電阻膜、數位三用電表和電瓶組裝一個準確、簡易的氣壓量測之儀器。

↓

實驗二：設計一可控制電阻膜兩端氣壓差的裝置，並找出壓力差與其對應電位差之關係，以製作此儀器的檢量線，作為後續實驗之應用。

↓

實驗三：
探討不同比例混合液體之蒸氣壓關係，以驗證拉午耳定律。

實驗五：
探討不同氣體的溶解度與分壓力之關係，以驗證亨利定律。

以自製儀器來驗證課本理論，並將其應用性擴展至其他氣體壓力的測量上。

↓

實驗四：
利用液體純質在不同溫度下的蒸氣壓來推求汽化熱(ΔH)。

實驗六：
設計簡易方法搭配自製儀器，測定愛河水質的 B.O.D. 值(生化需氧量)。

實驗七：
探討給呂薩克定律(P~T 關係)，利用外差法來推求絕對零度。

↓

綜合以上結果來進行討論，歸納出結論，並探討此氣壓量測器的效果。

【實驗一】組裝準確、簡易的氣壓量測之儀器

一、實驗設計：利用簡單便宜的零件及電子元件來組裝一可測量氣體壓力的裝置。

二、儀器的設計：

　　(一)以電阻膜連接於電路 IC 板上，將兩端感測之氣壓差值表現在電阻膜的電壓變化上。

　　(二)電阻膜兩側分別與不同之壓力系統相連：一端連接大氣，另一端連接待測壓力系統。
　　　　因待測壓力系統非真空，故系統內原來就有大氣壓，故兩端的壓力差即為待測的蒸氣
　　　　壓或氣壓。

　　(三)將電路板連接電瓶與三用電表，並製作氣壓與電壓的檢量線，讀取電壓以便能知道待
　　　　測壓力系統的氣壓。

　　(四)待測的壓力環境依各實驗之需求不同，而設計了不同的測定裝置：(如下圖所示)

　　1. 如圖 1-1 所示，利用電子元件—電路
　　　　IC 板、電阻膜、數位三用電表和電瓶
　　　　組裝一個準確、簡易的氣壓量測之儀器。

圖 1-1

　　2. 實驗二：設計實驗裝置以改變電阻膜
　　　　兩端的氣壓差，找出壓力差與其對應
　　　　的電位差之關係，以製作此儀器的檢
　　　　量線，以作為後續實驗之應用。

圖 1-2

　　3. 實驗三：設計實驗裝置來探討蒸氣壓和
　　　　混合液體之關係，以驗證拉午耳定律。
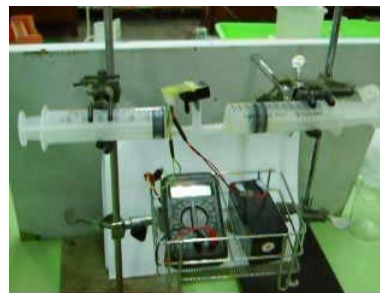

圖 1-3

　　4. 實驗四：設計實驗裝置來推求液體純質
　　　　　之汽化熱(ΔH)。

圖 1-4

圖 1-5

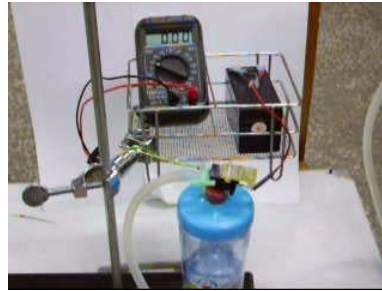5. 實驗五：設計實驗裝置來並探討不同氣體之溶解度與其分壓之關係，
以驗證亨利定律。

圖 1-6

圖 1-7

6. 實驗六：設計簡易方法搭配自製儀器，測定愛河水質的 B.O.D. 值(生化需氧量)。

圖 1-8

圖 1-9

7. 實驗七：探討給呂薩克定律(P~T 關係)，利用外差法來推求絕對零度。

圖 1-10

三、儀器的設計及改良：

(一)本實驗將自製氣壓量測器以焊錫固定於 IC 電路板上，並連接三用電表、充電電瓶來
組裝成本研究的裝置。自製氣壓量測器內為一極靈敏的電阻膜，膜兩側之壓力差會
造成電組膜的形變，進而造成電阻值的改變。以 IC 電路板連接電瓶形成一通路，利
用三用電表讀取自製氣壓量測器兩端之電壓值，即可推算出電阻膜兩端之氣壓差。
改良：將 IC 電路板裁切成較小面積以方便連接於各實驗裝置。電阻膜兩端之氣壓差
取一端連通至大氣，另一端連接待測壓力系統。因待測壓力系統非真空，故
系統內原來就有大氣壓，故兩端的壓力差即為待測的蒸氣壓或氣壓。

(二)在實驗二中，以有側管的錐形瓶做為一密閉空間，側管處以塑膠管連接抽氣機以改
變瓶內外壓力差，瓶口以橡皮塞密封，並鑽孔連接自製氣壓量測器及水銀壓力裝置
改良 1 以不透氣膠帶、熱熔膠，使側管與抽氣之塑膠管及自製氣壓量測器完全密合，
更準確地製作自製氣壓量測器之檢量線。
改良 2 搭配物理實驗上學到的水銀壓力裝置，利用學校物理實驗室就有的水銀壓力
裝置可以更精密地製作出自製氣壓量測器之檢量線。

(三)在實驗三中，將兩個體積相等的針筒連接 T 形管兩端，第三端連接自製氣壓量測器，
以 T 形管做為氣室，推動左側針筒並同時拉動右側針筒，使氣室體積維持一定，以
排除體積改變對蒸氣壓的影響。
改良：將針筒之注射尖口截去，並於實驗操作時將裝置略為向右側(液體抽取端)傾
斜，以將管中液體完全抽出。

(四)在實驗四中，以寶特瓶為待測純質液體之容器，在瓶蓋上鑽孔連接自製氣壓量測器，
並在其側穿孔，連接三通閥做為開關，以便調節內外壓力差。將寶特瓶置於恆溫槽
中加熱，以改變溫度測量不同溫度下對應的蒸氣壓值，並以鐵架固定寶特瓶避免恆
溫槽中循環水流所造成的晃動。
改良 1 以橡皮塞代替瓶蓋，與自製氣壓量測器並以 AB 膠及塑鋼土使之密合連接，並
增加一孔裝入溫度計，以測得待測液體之準確溫度數值，取代恆溫槽的設定
溫度，避免瓶內外溫度不一造成誤差。
改良 2 每次操作實驗時，先將待測液體加熱至一致的起始溫度，以統一換算因瓶內
空氣加熱後造成的壓力變化，修正讀取的蒸氣壓數值造成的誤差。

(五)在實驗五中，橡皮塞增加一孔連接三通閥做為開關，連接裝有待測氣體之鋼瓶，通
入氣體以改變杯中該氣體之分壓。加壓完畢達平衡狀態後，改以針筒連接三通閥緩
慢抽取裝置中的氣體，使氣壓緩慢降低，以避免氣壓快速下降而造成的溶解氣體從
水中溢出。
改良 1 待測壓力系統之容器，經過幾次實驗發現，用寶特瓶容易因實驗中內外壓力
差改變過大而變形，所以最後選擇使用壓克力杯，以減少因容器變形造成的
實驗誤差。
改良 2 由於此實驗探討亨利定律，針對難溶性氣體，其溶解度十分微小，傳統三用
電表不易測出其所造成的電壓變化，所以嘗試將此裝置連接數位三用電表至
電腦上以便能更精確地測量其變化量。

(六)在實驗六中，將寶特瓶置於超音波震盪器中，使溶於河水中的各氣體完全溢出後，
通入氧氣使達飽和，再測出此河水的最大溶氧量，以做為未經超音波震盪之河水可
再溶解之氧量的比較值，推算出河水的實際溶氧量。

【實驗二】製作此儀器之氣壓差與電壓的檢量線

一、實驗設計：連接抽氣機，控制電阻膜兩端的壓力差，紀錄其電壓值變化，以製作此儀器的檢量線。

操縱變因	電阻膜兩端的壓力差
控制變因	電路總電阻、電瓶電壓、錐形瓶容積

二、實驗步驟：

(一)將此儀器之電阻膜一端連接錐形瓶，再由側管連接抽氣機，將抽氣機連接至錐形瓶之另一端，控制錐形瓶壓力環境，並以開關控制，使此儀器與錐形瓶形成密閉環境。

(二)以抽氣機將錐形瓶內之壓力抽至最低值(此時抽氣機之氣壓計讀數相對於當時大氣壓為-710mmHg)，並讀取此時之電壓值，再由開關控制使錐形瓶內之氣壓逐漸回升至一大氣壓，在此過程中控制氣壓間隔為 50 mmHg，讀取不同氣壓對應之電壓值，觀察並紀錄兩者關係。

(三)重複以上之過程紀錄不同壓力差與電壓之關係，每次實驗做三次，取其平均值，並製作出此氣壓量測器之檢量線。
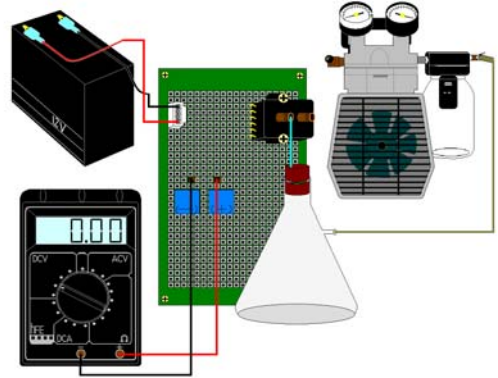
圖 2-1

三、數據及關係圖：

錐形瓶內外壓力差(mmHg)	760.00	710.00	660.00	610.00	560.00
錐形瓶內氣壓(mmHg)	0.00	50.00	100.00	150.00	200.00
相對電壓差(0.001 伏特)	0.00	28.40	51.60	75.23	103.54
錐形瓶內外壓力差(mmHg)	510.00	460.00	410.00	360.00	310.00
蒸氣壓(mmHg)	250.00	300.00	350.00	400.00	500.00
相對電壓差(0.001 伏特)	125.43	153.30	178.40	203.52	251.20

表 2-1
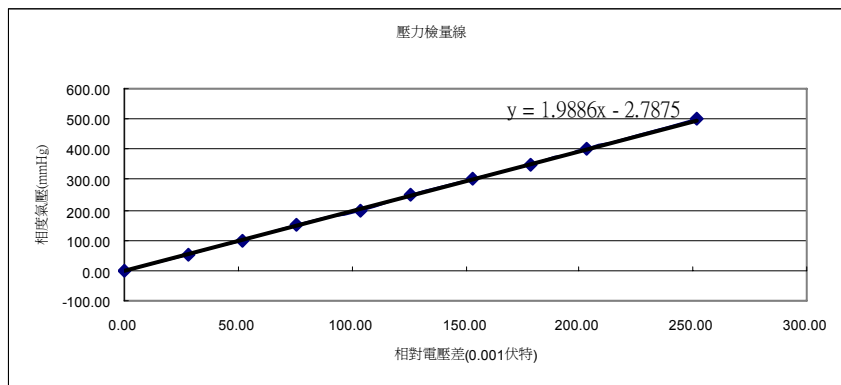
圖 2-2

四、結果及討論：

（一）利用抽氣機來控制整個系統的壓力變化，並配合我們自製的儀器，利用電壓來測量系
統壓力值的大小，發現兩者之間的 R^2 值高達 0.9997，整個圖形的線性關係為 y = 1.9886x
- 2.7875，測量的誤差值平均在 0.12％，最大誤差值為 2％，最小為 0.17％(上
述不包含 50mmHg)。這表示我們所用的儀器在測量空氣壓力的變化量呈現一個良好的
線性關係，並且有極高的正相關，故很適合用來測量容器內的壓力變化。

（二）利用本儀器可以簡易、快速的測量出壓力值，利用高的線性關係，可精密且正確的測
量實驗數據，有利於數據處理及推廣到其他氣體相關的實驗上。

（三）實驗改良：搭配物理實驗上學到的水銀壓力裝置，利用學校物理實驗室就有的水銀壓
力裝置可以更精密地製作出自製氣壓量測器之檢量線。

【實驗三】利用此儀器來探討拉午耳定律及溶液蒸氣壓之正負偏差關係

一、實驗設計：我們決定利用此裝置，配合壓力量感測器，測出純溶劑、純溶質及兩成份系
混合溶液的蒸氣壓，觀察其變化，找出其關係。

操縱變因	溶液種類與混合之比例
控制變因	氣室體積、溫度、電路總電阻、電瓶電壓

二、實驗步驟：

（一）以針筒抽取待測之混合溶液
體積。

（二）將裝有待測液體之針筒置於左
側，右側放置一空針筒，分別
接在 T 形管左右兩端。

（三）T 形管上端連接氣壓量測器。

（四）將左側針筒中之液體緩慢推入 T

圖 3-1

形管中，同時以右側針筒抽出 T 形管中之液體至 T 形管中恰無液體殘留。

（五）觀測滴入液體前後 T 形管內之氣壓變化，所測得之氣壓變化即為該溫度
下之液體飽和蒸氣壓值。

（六）測量此時實驗裝置的電壓，所得之電壓值再根據實驗二的檢量線，便可求得其蒸氣壓
值。（每次實驗做三次，再取平均值）

（七）由於混合後，溶液本身的溫度會有所變化，因此我們會靜置些許時間後，等壓力平衡
穩定時，再測其蒸氣壓(另用一組對照，在大氣下依相同比例混合後，用溫度計測
量，當成室溫)，故蒸氣壓的溫度會等於當時的室溫。
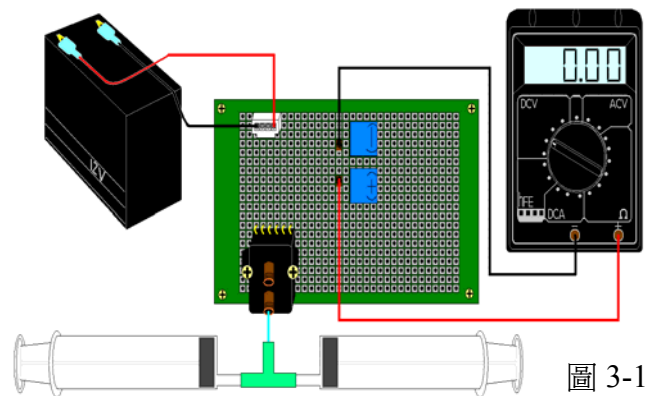
三、數據及分析
※ 實驗數據

（一）水 – 酒精(T=26.3℃)

水 (莫耳分率)	酒精 (莫耳分率)	測出電壓 (0.01 伏特)	(酒精與水)混合之 實測蒸氣壓 (mmHg)	溶液之理想 蒸氣壓 (mmHg)	酒精之理想 蒸氣壓 (mmHg)	水之理想 蒸氣壓 (mmHg)
1.00	0.00	12.77	22.61	22.61	0.00	22.61
0.90	0.10	13.12	23.31	25.74	5.35	20.39
0.80	0.20	13.94	24.94	28.78	10.69	18.09
0.70	0.30	14.99	27.03	31.87	16.04	15.83
0.60	0.40	16.13	29.29	34.95	21.38	13.57
0.50	0.50	17.18	31.73	38.04	26.73	11.31
0.40	0.60	19.43	35.86	41.11	32.07	9.04
0.30	0.70	21.68	40.33	44.20	37.42	6.78
0.20	0.80	24.15	45.23	47.28	42.76	4.52
0.10	0.90	26.27	49.46	50.37	48.11	2.26
0.00	1.00	28.28	53.45	53.45	53.45	0.00

表 3-1

圖 3-2

（二）丙酮 – 氯仿（T=25.9℃）

丙酮 (莫耳分率)	氯仿 (莫耳分率)	測出電壓 (0.01 伏特)	(丙酮與氯仿)混合 之實測蒸氣壓 (mmHg)	溶液之理想 蒸氣壓 (mmHg)	丙酮之理想 蒸氣壓 (mmHg)	氯仿之理想 蒸氣壓 (mmHg)
1.00	0.00	121.96	239.74	239.74	239.74	0.00
0.90	0.10	115.86	227.62	237.00	215.77	21.23
0.80	0.20	112.68	221.29	234.26	191.79	42.47
0.70	0.30	107.74	211.46	231.52	167.82	63.70
0.60	0.40	105.59	207.19	228.78	143.84	84.94
0.50	0.50	102.64	201.33	226.04	119.87	106.17
0.40	0.60	103.69	203.42	223.30	95.90	127.40
0.30	0.70	105.91	207.82	220.56	71.92	148.64
0.20	0.80	107.11	210.21	217.82	47.95	169.87
0.10	0.90	106.58	209.15	215.08	23.97	191.11
0.00	1.00	108.18	212.34	212.34	0.00	212.34

表 3-2

圖 3-3

（三）苯－甲苯(T=26.4℃)

苯 (莫耳分率)	甲苯 (莫耳分率)	測出電壓 (0.01 伏特)	(苯與甲苯)混合 之實測蒸氣壓 (mmHg)	溶液之理想 蒸氣壓 (mmHg)	苯之理想 蒸氣壓 (mmHg)	甲苯之理想 蒸氣壓 (mmHg)
1.00	0.00	10.76	112.56	112.56	112.56	0.00
0.90	0.10	17.89	103.25	104.52	101.30	3.22
0.80	0.20	21.67	95.17	96.48	90.05	6.43
0.70	0.30	23.76	86.83	88.44	78.79	9.65
0.60	0.40	25.73	77.72	80.40	67.54	12.86
0.50	0.50	27.42	69.86	72.36	56.28	16.08
0.40	0.60	27.89	62.18	64.31	45.02	19.29
0.30	0.70	28.15	54.93	56.28	33.77	22.51
0.20	0.80	28.42	47.66	48.23	22.51	25.72
0.10	0.90	28.53	39.21	40.20	11.26	28.94
0.00	1.00	28.28	32.15	32.15	0.00	32.15

表 3-3
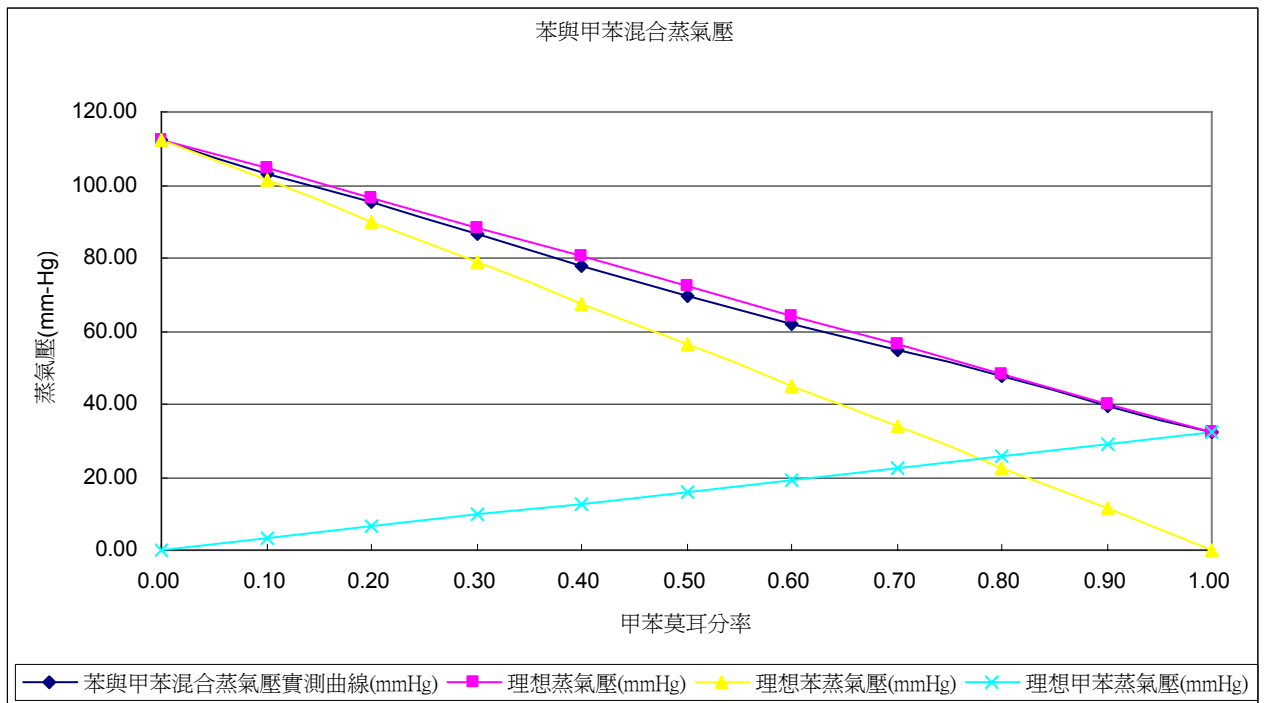
圖 3-4

四、實驗結果與討論

　　(一)從實驗數據中可推測，水與酒精因為都具有分子間氫鍵，而且兩者都為極性分子，互溶性相當好，分子不易脫離生成蒸氣部分，而降低原蒸氣壓力。然而分子相互間的結合力也較原來分子的結合力強，所以混合後會造成負偏差的情形。

　　(二)由圖形可以發現，當兩個分子間的莫耳分率越接近時，其偏差的情況會更佳明顯。而當莫耳分率差異越大時(接近稀薄溶液)，發現偏差情形較不明顯。丙酮與氯仿的實驗結果大致也與水與酒精相同。

　　(三)在苯與甲苯的實驗中，由於兩者間的引力大小差距不大，但仍無法完全忽略兩者間的相互引力，因此還是會有所偏差。實驗明顯發現，兩者混合後所呈現的結果，仍呈現小部分的負偏差，但比起水與酒精及丙酮與氯仿的偏差情形小很多，故仍可近似推論至理想溶液的情形。

　　(四)根據上述實驗結果，本儀器所使用的方法與原理，可以推論出具有負偏差的實驗數據及相關的例子，故本儀器具有相當的準確性，可以應用於負偏差的實驗結果。

　　(五)1908 年，美國化學家 Gilbert N. Lewis 在文獻上發表逸壓 f (Fugacity)的概念如下：

　　　1.理想氣體與化學位能(Chemical potential)有如下關係：$\mu = \mu_o + RT \ln P/P_o$

　　　　定義真實氣體與化學位能也有相似關係　$\mu = \mu_o + RT \ln f/f_o$　　　$f = \Phi P$

　　　　Φf，逸壓--其單位與壓力相同，它取代了拉午耳定律中的壓力 P 。

　　　2.它的意義是在：真實狀況下，逸壓 f 取代理想狀況下的壓力 P，較準確地預測物質從事相的轉變(液變氣，氣變液)的趨勢，即化學位能(Chemical potential)。逸壓概念的提出，算是拉午耳定律的修正。故本實驗數據結果，仍可略為修正，會較附合真實情形，故本實驗在後續的研究將會繼續探討這個部分。

【實驗四】利用自製儀器來推求液體純質之汽化熱(ΔH)

一、實驗設計：利用此裝置，配合壓力量測器，測出液體純質在不同溫度下的蒸氣壓，並利用 clausius－clapeyron equation 求出汽化熱(ΔH)。

操縱變因	純質液體溫度、純質液體種類
控制變因	純質液體體積、電路總電阻、電瓶電壓、寶特瓶容積

二、實驗步驟：

（一）將待測液體在燒杯中加熱至起始溫度（30℃），倒入寶特瓶中，並打開三通閥使內外壓力一致。

（二）以橡皮塞密封並連接氣壓量測器裝置，並關上三通閥。

（三）將寶特瓶置於恆溫槽內，改變恆溫槽的溫度，待平衡後，以壓力量測器測量此時之蒸氣壓，並讀取此時溫度計的讀數。

圖 4-1

（四）重複步驟一、二、三，測量不同溫度下的蒸氣壓值。

（五）分別以水、酒精、丙酮進行以上步驟，記錄壓力與溫度之變化關係。
（六）每種純質液體實驗三次，再取平均值。

三、數據及分析

（一） 水
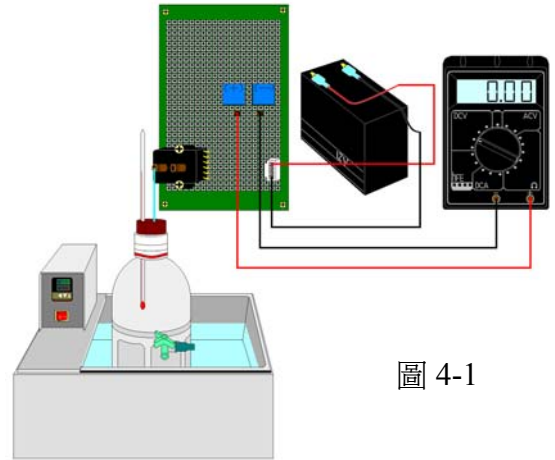
t (℃)	T(k)	P(水)mmHg	1/T	logP(水)
55.00	328.00	121.65	0.0030	2.09
50.00	323.00	92.95	0.0031	1.97
40.00	313.00	55.14	0.0032	1.74
30.00	303.00	31.53	0.0033	1.50

表 4-1

$$y = -2322.2x + 9.1616$$
$$R^2 = 0.9999$$

圖 4-2

（二）酒精
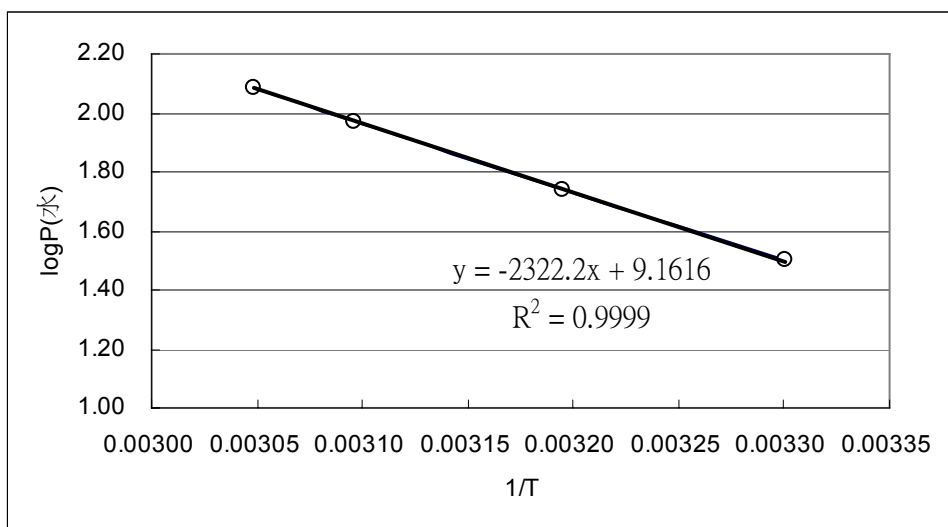
t（℃）	T(k)	P(乙醇)mmHg	1/T	logP(乙醇)
55.00	328.00	202.27	0.0030	2.31
50.00	323.00	172.71	0.0031	2.24
40.00	313.00	123.15	0.0032	2.09
30.00	303.00	84.32	0.0033	1.93

表 4-2

$y = -1510.4x + 6.9126$

$R^2 = 0.9998$

圖 4-3

（三）丙酮
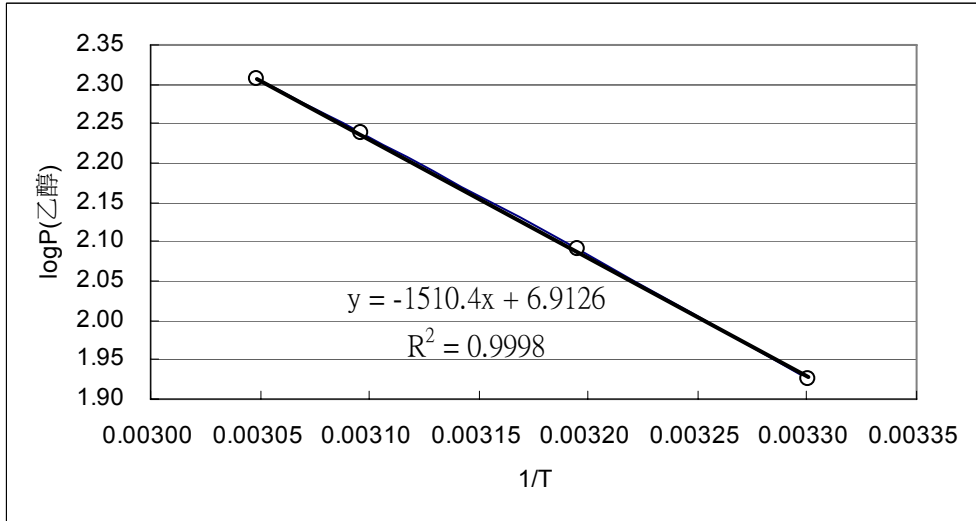
t（℃）	T(k)	P(丙酮)mmHg	1/T	logP(丙酮)
55.00	328.00	844.27	0.0030	2.93
50.00	323.00	672.71	0.0031	2.83
40.00	313.00	463.15	0.0032	2.67
30.00	303.00	337.42	0.0033	2.53

表 4-3

$y = -1569.9x + 7.6979$

$R^2 = 0.9923$

圖 4-4
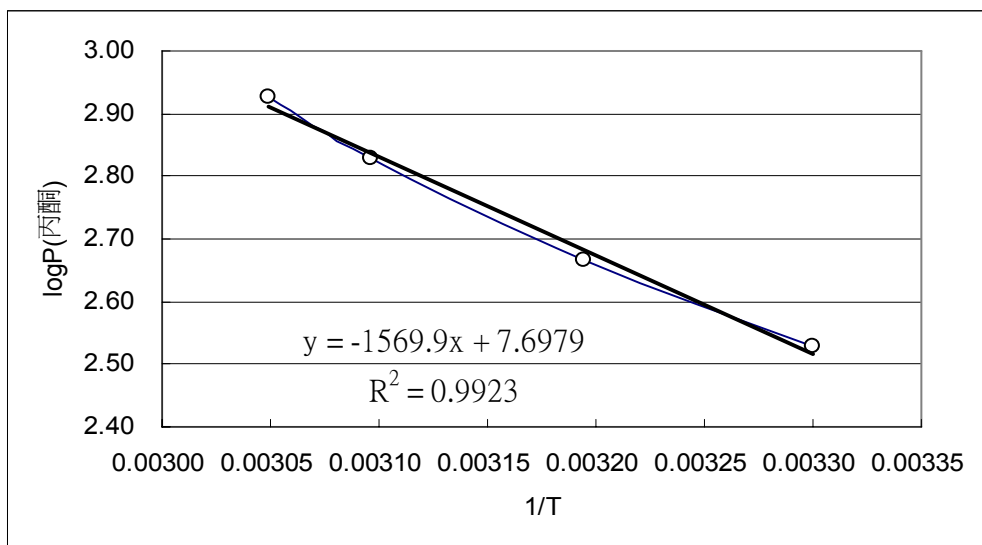
四、實驗結果與討論

(一)因為加溫至 60℃ 後，容器會變形，故易造成誤差，所以本實驗的溫度最高僅做到 55℃。

(二)由於本身溶液在加熱過程中恒溫槽的溫度不易達到熱均勻，經改良後，在瓶內加裝溫度計，以便能更準確地測得瓶內的水溫。

(三)從 30℃ 開始測量壓力值，之後持續加溫，並測量壓力變化。空氣壓力的部分可由 $P_1/T_1=P_2/T_2$ 修正之，並推算出液體的蒸氣壓。

(四)由於加溫時，壓力增大，造成氣體溶解度也隨之上升，故經本儀器所測量出的蒸氣壓，扣除空氣壓力膨脹的因素後應會略小於實際值。

(五)由 clausius－clapeyron equation 分別求出汽化熱(如表 4-4)。

	實驗值	理論值
水的汽化熱(cal/mole)	9626.5	9737
乙醇的汽化熱(cal/mole)	8911.7	9222
丙酮的汽化熱(cal/mole)	7183.0	7488

表 4-4

(六)為了避免因加熱過程中，空氣的壓力會因為加熱而增大，造成實驗的誤差。因此，**改良方法**：將容器先泡入水中，只露出瓶蓋，並先將欲注入的液體也用水浴加熱至起始溫度。此時，將加入液體容器接上後，先將瓶上開關打開，瞬間內外連通後，達平衡後關上三通閥。此時並打入液體，增加瓶內體積(參考實驗步驟一)。

【實驗五】探討亨利定律及不同氣體之分壓力與溶解度關係

一、實驗設計：利用此壓力量測器，設計實驗裝置，來探討不同氣體溶解度與分壓力之關係，以驗證亨利定律。

操縱變因	待測氣體分壓、氣體種類
控制變因	壓克力杯容積、溫度、溶劑量、氣室體積、電路總電阻、電瓶電壓

二、研究過程：

(一) 想法及數學式導證：

1.想法：

從打開汽水瓶蓋逸出氣體的現象，聯想到高中課本中之亨利定律 $m = kp$ (m ：水中氣體溶解度； P ：氣體壓力； k ：常數)，並由此方程式推得 $\Delta m = k\Delta p$ ，所以由 Δm 、 Δp 可求出亨利定律常數 k 。
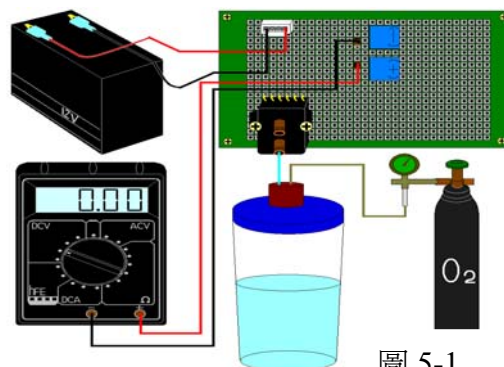
圖 5-1

2.數學式導證：

P_i ：初始壓力(飽和狀態)　　P_f ：末壓力（新平衡狀態）

V_g ：氣體體積　　V_e ：水溶液體積　　Δm ：溶解度變化量

Δp ：過飽和態與新平衡狀態之氣壓差

$$\Delta m = \frac{\Delta n}{V_e} = k(P_i - P_f)$$

再利用理想氣體方程式 $PV = nRT$ ，推得 $\Delta n = \dfrac{\Delta P \cdot V_g}{R \cdot T}$ ，可求出 k

(二) 實驗過程與技巧：

先製造一飽和態，讀出此平衡狀態之壓力 P_i ，再洩氣以製造過飽和狀態，初次實驗時因洩氣太快，導致水中氣體迅速逸出，因而無法確定溶解度變化量 Δm_1 。改進後，採用極緩慢之放氣方式以避免氣體大量逸出，成功地製造出過飽和態 P_{n1} ，再搖動使氣體逸出達新平衡狀態 P_{f1} ，如此繼續做下去，再緩慢洩氣得 P_{n2} ，搖動得 P_{f2} …在每一階段可得一個 k ，再以 m 、 P 作圖求出平均 k 值。

如此不僅方程式合而為一且只須如上述讀出 P_i 與每一階段 P_{ni} ， P_{f1} 即可得每一階段之 k ，並求出最準確之 k 值。以上為降壓求 k 之方式，若欲採增壓求 k ，同理可知，只須將灌氣達未飽和之壓 P_{ni} ，再搖動後達平衡之壓力 P_{fi} ，即可利用 $|P_n - P_f|$ 之值求得 Δm 。

三、實驗步驟：

(一)將寶特瓶連接壓力量測器，並將水注入瓶內。

(二)將待測氣體以排水集氣法加入瓶中，讀取三用電表之 V_i 讀數。

(三)以針筒抽氣，使瓶內壓力緩慢降低，讀取此時 V_n 讀數

(四)搖晃瓶身使過飽和氣體逸出，平衡後讀取 V_f 。

(五)重複不同 ΔP 下記錄不同的 Δm 。　　(實驗三次，再取平均值)

由 $(V_f - V_i)$ 換算出 ΔP - ①

由 $(V_f - V_n)$ 換算出 ΔP_m ，代入 $\Delta P_m V = \Delta nRT$ 求出 Δm - ②

由①、②代入 $\Delta m = k \cdot \Delta P$ 得 k 值

四、數據及分析

氣體種類：CO_2 溫度=23.4 ℃

（由實驗數據電壓值 V 推算出氣壓值 P）(-表小於一大氣壓)

實驗次數	一			二		
氣溫(℃)	23.4	23.4	23.4	23.4	23.4	23.4
氣體體積(mL)	101.00	101.00	101.00	101.00	101.00	101.00
水溶液體積(mL)	55.40	55.40	55.40	55.40	55.40	55.40
V_i(V)	0.035	0.031	0.019	0.013	0.009	0.002
P_i(mmHg)	826.81	818.85	794.99	783.06	775.10	761.18
V_n(V)	0.030	0.016	0.011	0.008	0.000	-0.002
P_n(mmHg)	816.87	788.63	779.57	772.922	757.21	753.65
V_f(V)	0.031	0.019	0.013	0.009	0.002	-0.001
P_f(mmHg)	818.85	794.99	783.06	775.10	761.18	755.23

表 5-1

實驗次數	三			四		
氣溫(℃)	23.3	23.3	23.3	23.3	23.3	23.3
氣體體積(mL)	101.00	101.00	101.00	101.00	101.00	101.00
水溶液體積(mL)	5450	55.40	55.40	50.50	50.50	50.50
V_i(V)	0.005	-0.001	-0.003	0.025	0.017	0.011
P_i(mmHg)	767.15	755.23	751.25	806.92	791.01	779.08
V_n(V)	0.000	-0.004	-0.007	0.015	0.010	0.03
P_n(mmHg)	757.21	749.27	741.31	787.03	776.29	764.03
V_f(V)	0.001	-0.003	-0.007	0.017	0.011	0.005
P_f(mmHg)	759.20	751.25	743.30	791.01	779.08	767.15

表 5-2

氣體種類：O₂ 　　溫度=23.2 ℃ 　　（–表小於一大氣壓）

實驗次數	一			二		
氣溫(℃)	24.0	24.0	24.0	24.0	24.0	23.9
氣體體積(mL)	137.6	137.6	137.6	137.6	137.6	137.6
水溶液體積(mL)	18.8	18.8	18.8	18.8	18.8	18.8
V_i(V)	0.046	0.037	0.030	0.027	0.004	0.019
P_i(mmHg)	848.68	830.78	816.86	810.90	765.16	794.99
V_n(V)	0.036	0.030	0.019	0.021	-0.003	0.004
P_n(mmHg)	828.79	816.68	794.74	798.84	751.09	764.88
V_f(V)	0.037	0.030	0.019	0.021	-0.003	0.004
P_f(mmHg)	833.57	816.86	794.99	798.97	751.25	765.16

表 5-3

實驗次數	三			四		
氣溫(℃)	23.9	23.9	23.9	22.8	22.8	22.8
氣體體積(mL)	105.4	105.4	105.4	126.6	126.6	126.6
水溶液體積(mL)	51.0	51.0	51.0	29.8	29.8	29.8
V_i(V)	0.021	0.014	0.001	0.045	0.044	0.053
P_i(mmHg)	798.97	784.45	759.20	846.69	844.70	862.60
V_n(V)	0.013	0.001	-0.006	0.039	0.032	0.044
P_n(mmHg)	783.06	758.22	744.79	834.51	820.40	844.37
V_f(V)	0.014	0.001	-0.006	0.039	0.032	0.044
P_f(mmHg)	785.05	759.20	745.29	834.76	820.84	844.70

表 5-4

實驗次數	五			六		
氣溫(℃)	22.0	22.0	22.0	22.0	22.0	22.0
氣體體積(mL)	107.0	107.0	107.0	107.0	107.0	107.0
水溶液體積(mL)	49.4	49.4	49.4	49.4	49.4	49.4
V_i(mV)	32.0	21.4	16.1	24.6	17.2	5.9
P_i(mmHg)	820.84	799.76	789.22	806.12	791.41	768.94
V_n(mV)	20.9	15.9	8.0	17.0	5.5	-9.5
P_n(mmHg)	798.97	788.82	773.12	791.01	768.14	738.33
V_f(mV)	21.4	16.1	8.1	17.2	5.9	-8.9
P_f(mmHg)	799.76	789.22	774.90	791.41	768.94	739.51

表 5-5

以前述方法求出不同氣體 k 值。Pm=Pf-Pn　　△P=Pf-Pi

CO_2 之 k 值

實驗次數	一	二	三	四
氣體種類	CO_2			
氣體體積 V_g (mL)	101.00	101.00	101.00	101.00
水溶液體積 V_t (mL)	55.40	55.40	55.40	50.50
氣溫(℃)	23.4	23.4	23.3	23.3
P_{i1} (mmHg)	826.81	783.06	767.15	806.92
P_{n1} (mmHg)	816.87	772.922	757.21	787.03
P_{f1} (mmHg)	818.85	775.10	755.23	791.01
△P_1 (mmHg)	7.96	7.96	7.96	15.91
Pm_1 (mmHg)	1.98	2.178	1.99	3.98
△m_1(mM))	0.1954	0.2140	0.1964	0.4310
k_1(mM/ mmHg)	2.45×10^{-2}	2.69×10^{-2}	2.46×10^{-2}	2.70×10^{-2}
P_{i2}(mmHg)	818.85	775.10	755.23	791.01
P_{n2}(mmHg)	788.63	757.21	750.26	776.29
P_{f2} (mmHg)	794.99	761.18	751.25	779.08
△P_2 (mmHg)	23.86	13.92	3.98	11.93
Pm_2 (mmHg)	6.36	3.97	0.99	2.786
△m_2(mM))	0.6277	0.3918	0.0977	0.2961
k_2(mM/ mmHg)	2.65×10^{-2}	2.81×10^{-2}	2.45×10^{-2}	2.52×10^{-2}
P_{i3}(mmHg)	794.99	761.18	751.25	779.08
P_{n3}(mmHg)	779.57	753.65	741.31	764.03
P_{f3}(mmHg)	783.06	755.23	743.30	767.15
△P_3(mmHg)	11.93	5.95	7.95	11.93
Pm_3(mmHg)	3.49	1.58	1.99	3.12
△m_3(mM)	0.3441	0.1556	0.1964	0.3448
k_3 (mM/ mmHg)	2.88×10^{-2}	2.62×10^{-2}	2.47×10^{-2}	2.89×10^{-2}
A:截距	2.32×10^{-3}	2.32×10^{-3}	4.52×10^{-3}	3.85×10^{-3}
R:相關係數	0.9999	0.9995	0.999	0.9996
k 值	2.66×10^{-2}	2.71×10^{-2}	2.46×10^{-2}	2.70×10^{-2}

表 5-6

O_2 之 k 值

實驗次數	一	二	三	四	五	六
氣體種類	O_2					
氣體體積 V_g (mL)	137.6	137.6	105.4	126.6	107.0	107.0
水溶液體積 V_t (mL)	18.8	18.8	51.0	29.8	49.4	49.4
氣溫(℃)	24.0	24.0	23.9	22.8	22.0	22.0
P_{i1} (mmHg)	848.68	810.90	798.97	846.69	820.84	806.12
P_{n1} (mmHg)	833.41	798.84	784.45	834.51	798.97	791.01
P_{f1} (mmHg)	833.57	798.97	785.05	834.76	799.76	791.41
$\triangle P_1$ (mmHg)	15.11	11.93	13.92	11.93	21.08	14.71
Pm_1 (mmHg)	0.16	0.13	0.60	0.25	0.79	0.40
$\triangle m_1$(mM)	0.0630	00524	0.0666	0.0573	0.0930	0.0471
k_1(mM/ mmHg)	4.17×10^{-3}	4.39×10^{-3}	4.77×10^{-3}	4.80×10^{-3}	4.4×10^{-3}	3.2×10^{-3}
P_{i2}(mmHg)	830.78	765.16	785.05	844.70	799.76	791.41
P_{n2}(mmHg)	816.68	751.09	758.22	820.40	788.82	768.14
P_{f2} (mmHg)	816.86	751.25	759.20	820.84	789.22	768.94
$\triangle P_2$ (mmHg)	13.92	13.91	25.85	23.86	10.54	22.47
Pm_2 (mmHg)	0.18	0.16	0.98	0.44	0.40	0.80
$\triangle m_2$(mM)	0.0715	0.025	0.1111	0.1019	0.0471	0.0942
k_2(mM/ mmHg)	5.14×10^{-3}	4.68×10^{-3}	4.25×10^{-3}	4.32×10^{-3}	4.4×10^{-3}	4.1×10^{-3}
P_{i3}(mmHg)	816.86	794.99	759.20	862.60	789.22	768.94
P_{n3}(mmHg)	794.74	764.88	744.79	844.37	774.37	738.33
P_{f3}(mmHg)	794.99	765.16	745.29	844.70	774.90	739.51
$\triangle P_3$(mmHg)	21.87	29.83	13.91	17.90	14.32	29.43
Pm_3(mmHg)	0.25	0.28	0.50	0.33	0.53	1.18
$\triangle m_3$(mM)	0.0983	0.1124	0.0555	0.0760	0.0629	0.1390
k_3(mM/ mmHg)	4.49×10^{-3}	3.76×10^{-3}	3.98×10^{-3}	4.23×10^{-3}	4.38×10^{-3}	4.6×10^{-3}
A:截距	2.32×10^{-3}	2.32×10^{-3}	4.52×10^{-3}	3.85×10^{-3}	4.52×10^{-3}	3.85×10^{-3}
R:相關係數	0.9999	0.9995	0.999	0.9996	0.999	0.9996
k 值	4.60×10^{-3}	4.28×10^{-3}	4.33×10^{-3}	4.45×10^{-3}	4.39×10^{-3}	3.97×10^{-3}

表 5-7

五、實驗結果與討論

1. CO_2 與 O_2 之平均 k 值為：CO_2：2.63×10^{-2} mM， O_2： 4.34×10^{-3} mM

   由此裝置則測得水溶液液面上氧氣(二氧化碳)分壓即可推知該氣體的溶解度

2. CO_2 與 O_2 的 k 值對壓力的關係為： CO_2 的 k 值於壓力大時呈現正偏差，可知亨利定律適用於低溫低壓條件下、難溶性的氣體； O_2 溶解度與氧氣壓力成正比關係，由此印證亨利定律。

3. 實驗操作中以排水集氣法注入氧氣(二氧化碳)，使進行升降壓時空氣與注入氣體的比例不任意變動，此時測得的系統總壓即為該氣體的分壓。

4 控制初始氧氣(二氧化碳)之壓力，所得不同的初始平衡壓力分別為不同的平衡狀態，由不同的初始壓力可測得壓力對 k 值的影響，以探討亨利定律。

5. 實驗過程中加壓和減壓時，搖晃錐形瓶身可增加水溶液與氣體的接觸面積，加速達成溶解平衡。

【實驗六】利用壓力量測器來測定愛河水質之 B.O.D.值

一、實驗設計：設計簡易方法搭配自製儀器，測定愛河上、中、下游及出海口水質的 B.O.D.值(生化需氧量)。

操縱變因	不同河段(上游、中游、下游及出海口)之河水
控制變因	溫度、氧氣分壓、待測河水量、氣室體積、電路總電阻、電瓶電壓、寶特瓶容積

二、實驗步驟：

(一)取各河段之水，以超音波震盪器使其中溶有之氣體全部逸出。

(二)將 O_2 以排水集氣法灌入瓶中，水完全排出後再持續注入 O_2。

(三)再以針筒迅速注入待測河水後，讀取此時氣壓量測器之讀數 $P_1(V_1)$。

圖 6-1

(四)待溶解平衡後，讀取此時 $P_2(V_2)$，由 $(V_2 - V_1)$ 換算出 ΔP_m，代入 $\Delta P_m V = \Delta nRT$ 求出河水可溶 O_2 的最大值 m_0。

(五)再取河水(未震盪)重複步驟 2、3，讀數 P_3、P_4，由 $(V_4 - V_3)$ 換算出 $\Delta P_m'$ 代入 $\Delta P_m V = \Delta nRT$ 求出原河水可再溶之 O_2 量 Δm。

(六)將 $m_0 - \Delta m = m$，即為河水中的溶 O_2 量。m_0：河水的最大溶氧量

註：由 Δm 大小可推測溶 O_2 量，但不同河段之 m_0 可能不同。
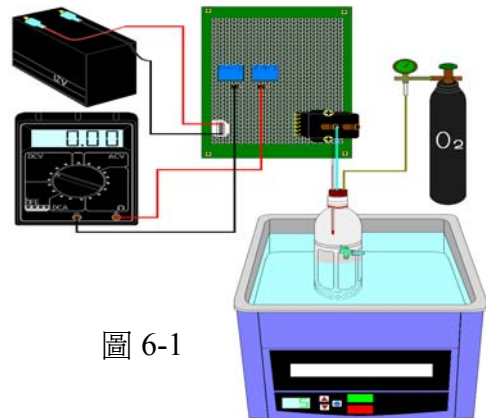
三、數據及分析

※愛河上游

實驗次數		一	二	三	四
河水體積(mL)		50.0	50.0	50.0	50.0
氣體體積(mL)		106.4	106.4	106.4	106.4
日期		1/24	1/27	1/28	1/31
溫度($^{\circ}$C)		21.5	19.9	20.0	19.5
已震盪	V1(mV)	42.0	42.6	39.6	38.2
	P1(mmHg)	840.73	841.92	835.96	833.17
	V2(mV)	40.0	40.4	37.3	36.5
	P2(mmHg)	836.75	837.55	831.38	829.79
未震盪	V3(mV)	41.1	47.1()	37.8	41.1
	P3(mmHg)	838.94	850.87	832.38	838.94
	V4(mV)	39.3	46.1	36.2	39.7
	P4(mmHg)	835.36	848.88	829.19	836.15
溶氧量(mM)		0.0870	0.0533	0.0309	0.0065

表 6-1

※愛河中游

實驗次數		一	二	三	四
河水體積(mL)		50.0	50.0	50.0	50.0
氣體體積(mL)		106.4	106.4	106.4	106.4
日期		1/25	1/27	1/30	1/31
溫度($^{\circ}$C)		20.0	19.5	20.8	19.5
已震盪	V1(mV)	42.1	30.8	37.3	40.8
	P1(mmHg)	840.93	818.46	831.38	838.34
	V2(mV)	39.8	29.6	36.2	39.2
	P2(mmHg)	836.35	816.07	829.19	835.16
未震盪	V3(mV)	48.0	31.1	39.0	38.8
	P3(mmHg)	852.66	819.05	834.76	834.28
	V4(mV)	46.0	30.1	38.0	37.2
	P4(mmHg)	848.68	817.06	832.77	831.18
溶氧量(mM)		0.0145	0.0092	0.0047	0.0015

表 6-2

※愛河下游

實驗次數		一	二	三	四
河水體積(mL)		50.0	50.0	50.0	50.0
氣體體積(mL)		106.4	106.4	106.4	106.4
日期		1/25	1/27	1/28	1/31
溫度($^\circ$C)		21.5	19.9	21.5	19.5
已震盪	V1(mV)	44.5	50.9	47.3	32.0
	P1(mmHg)	845.70	858.43	851.27	820.84
	V2(mV)	42.2	49.3	46.5	30.8
	P2(mmHg)	841.13	855.25	849.68	818.46
未震盪	V3(mV)	51.0	45.2	10.2	43.4
	P3(mmHg)	858.63	847.09	777.49	843.51
	V4(mV)	50.0	44.5	9.9	42.2
	P4(mmHg)	856.64	845.70	776.89	841.13
溶氧量(mM)		0.564	0.0384	0.0202	0.0015

表 6-3

※愛河出海口

實驗次數		一	二	三	四
河水體積(mL)		50.0	50.0	50.0	50.0
氣體體積(mL)		106.4	106.4	106.4	106.4
日期		1/26	1/27	1/30	1/31
溫度($^\circ$C)		21.0	19.8	21.0	18.0
已震盪	V1	12.0	43.1	30.4	36.9
	P1(mmHg)	781.08	842.92	817.67	830.59
	V2	10.7	41.8	29.4	35.7
	P2(mmHg)	778.49	840.33	815.68	828.20
未震盪	V3	10.3	33.0	40.5	39.3()
	P3(mmHg)	777.69	822.83	837.75	835.36
	V4	9.9	32.4	39.8	38.1
	P4(mmHg)	776.89	821.64	836.35	832.97
溶氧量(mM)		0.0424	0.0302	0.0123	0.0003

表 6-4

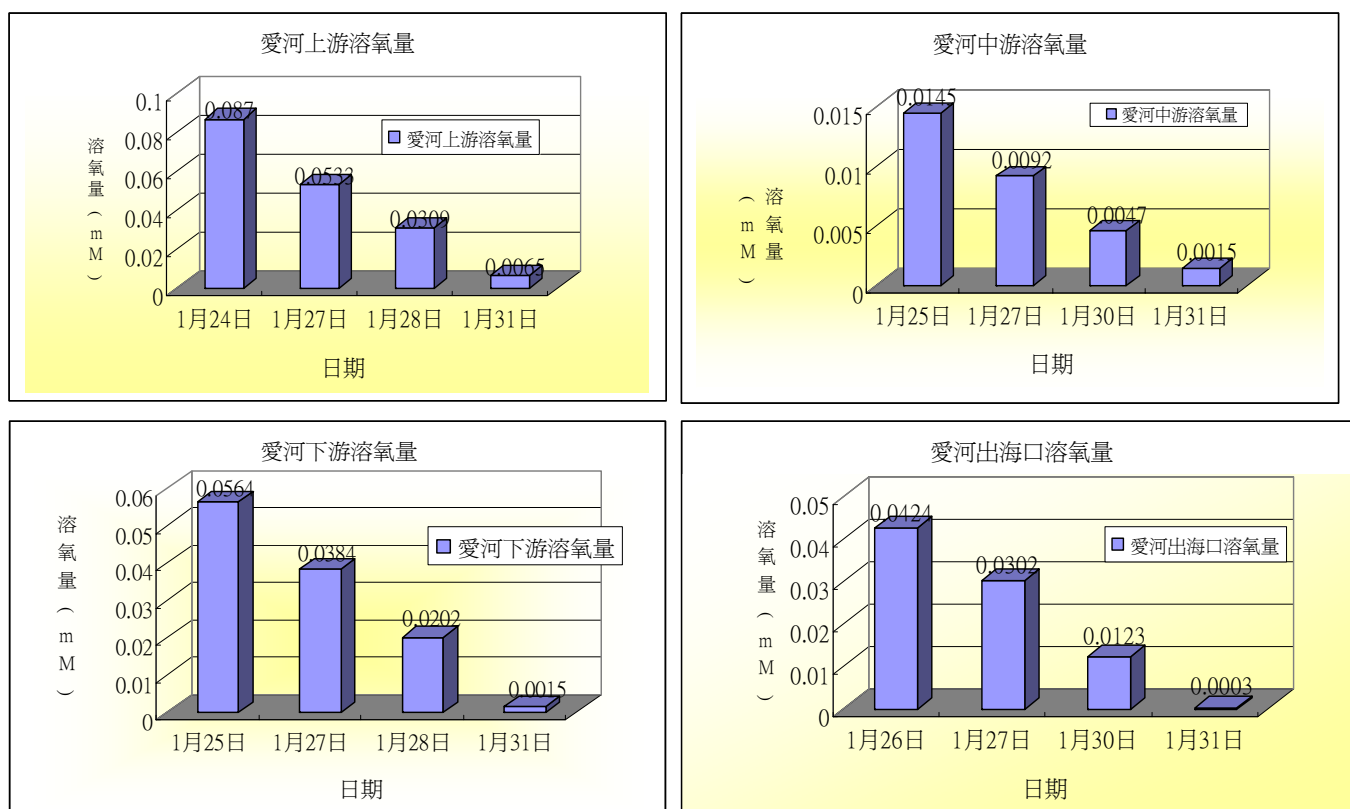欲比較各河段河水可再溶的氧量時，需依測量時的氧氣分壓換算成一致標準再比較(高壓較利於氧氣溶解故以較大氧氣壓力進行測量)

圖6-2~5

愛河水B.O.D.值

			上游	中游	下游	出海口
河水體積(mL)			50.0	50.0	50.0	50.0
氣體體積(mL)			106.4	106.4	106.4	106.4
第一天	溫度(℃)		19.8	19.5	19.9	19.7
	已震盪	P1(mmHg)	841.92	840.93	858.43	842.92
		P2(mmHg)	837.5	836.35	855.25	840.33
		m (mM)	0.0967	0.1015	0.0688	0.0571
	未震盪	P3(mmHg)	850.87	819.05	847.09	822.83
		P4(mmHg)	848.88	817.06	845.70	821.64
		△m(mM)	0.0434	0.0587	0.0304	0.0268
	m_0(mM)		0.0533	0.0428	0.0384	0.0303
第五天	溫度(℃)		19.5	19.5	19.5	19.5
	已震盪	P1(mmHg)	833.17	838.34	820.84	830.59
		P2(mmHg)	829.79	835.16	818.46	828.20
		m(mM)	0.0755	0.0705	0.0539	0.0535

未震盪	P3(mmHg)	838.94	834.28	843.51	835.36
	P4(mmHg)	836.15	831.18	841.13	832.97
	△m(mM)	0.0690	0.0691	0.0524	0.0532
	m_0(mM)	0.0065	0.0014	0.0015	0.0003
B.O.D. (mM)		0.0468	0.0414	0.0369	0.0300

表 6-5

愛河上游	愛河中游	愛河下游	出海口

四、實驗結果與討論

1.各河段的 B.O.D.值如右。
上游＞中游＞下游＞出海口

	上游	中游	下游	出海口
B.O.D. (mM)	0.0468	0.0414	0.0369	0.0300

2.各河段河水的含氧量關

係為：上游＞中游＞下游＞出海口,河水中的含氧量隨時間遞減趨勢如上圖。

3.實驗中測得各河段河水可再溶的氧量時，依測量時的氧氣分壓換算成一致標準再比較，換算方式如右：測得溶氧量×空氣中氧氣分壓÷平衡末壓

4.實驗操作時先以排水集氣法注入氧氣，再加壓至初始壓力後再注入河水，可減少氧氣與河水接觸時間，降低實驗誤差。

5. 生化需氧量(biochemical oxygen demand，簡稱 BOD)

(1)定義：細菌在污水中分解廢料所消耗的氧之總量稱生化需氧量即 BOD。

(2)測定法：

① 以蒸餾水保持 20°C，充氧氣使成飽和，並測溶氧量。

② 將待測廢水取一定量置於該蒸餾水，並保持 20°C 培養 5 日(需隔絕外界氧)再測水中剩下之溶氧量。

此實驗操作法培養過程，以保溫杯達到定溫密閉的穩定系統，測量時因另有氧氣壓力的變化，故取部分河水以採樣方式測量。

6.測量溶氧量時，分別測已震盪及未震盪河水氧氣壓力的變化量相互比較可得原溶液的最初溶氧量，採用間接的方式求得河水溶氧量，若直接測量河水受震盪時的壓力變化，來推算溶氧量，因壓力變化可能源自氧氣之外其他溶於河水中的氣體，易有誤差，故以間接法求得。

【實驗七】探討給呂薩克定律(P~T關係)，利用外差法來推求絕對零度

一、實驗設計：探討給呂薩克定律(P~T 關係)，利用外差法來求得絕對零度。

操縱變因	溫度、氣體種類
控制變因	錐形瓶容積、待測氣體莫耳數、電路總電阻、電瓶電壓

二、實驗步驟：

(一)利用氣體鋼瓶通入待測氣體，並以排水集氣法
將定量待測氣體收集於錐形瓶內，讀取此時三
用電表的電壓值。

(二)以恆溫槽加熱，平衡後讀取溫度與其所對應的
電壓值，並推算出此時的氣壓。

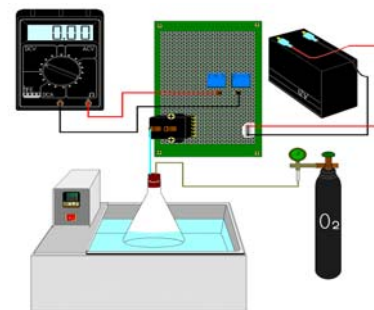(三)將氣壓(P)與絕對溫度(T)作圖，並利用外插法
來推算絕對零度。

(四)以不同氣體探討氣體的理想性與絕對零度之關係。

圖 7-1

陸、研究結果

一、實驗二中，製作的檢量線中壓力與電壓的關係，發現兩者之間的 R^2 值高達 0.9997，整個圖形的線性關係為 y = 1.9886x - 2.7875，測量的誤差值平均在 0.12%，最大誤差值為 2%，最小為 0.17%(上述不包含 50mmHg)。這表示我們所用的儀器在測量空氣蒸氣壓的變化量呈現一個線性關係，並且有很高的正相關，故適合用來測量容器內的壓力變化。

二、實驗三中，水與酒精因為都具有分子間氫鍵，而且兩者都為極性分子，互溶性相當好。然而分子相互間的結合力也較原來分子的結合力強，所以混合後會形成負偏差的情形。而當莫耳分率差異越大時(接近稀薄溶液)，發現偏差情形較不明顯。丙酮與氯仿的實驗結果大致也與水與酒精相同。在苯與甲苯的實驗中，由於兩者間的引力大小相距不大，實驗明顯發現，兩者混合後所呈現的結果，仍呈現小部分的負偏差，但比起水與酒精及丙酮與氯仿的偏差情形小很多，故仍可有效推論至理想溶液的情形。

三、實驗四中，將溫度與蒸氣壓的實驗值由 clausius－clapeyron equation 分別求出水、乙醇、丙酮的汽化熱如下：水 9626.52(cal/mole)，乙醇 8911.7 (cal/mole)，丙酮 7183 (cal/mole)；本實驗之實驗值與理論值相差不大，誤差值平均在 1%以下。

四、實驗五中.CO_2 與 O_2 之平均 k 值，CO_2：2.63×10^{-2} mM， O_2： 4.34×10^{-3} mM；CO_2 與 O_2 的 k 值對壓力的關係為： CO_2 的 k 值於壓力大時呈現正偏差，可知亨利定律適用於低溫低壓條件下、難溶性的氣體； O_2 溶解度與氧氣壓力成正比關係，由此印證亨利定律。

五、實驗六中，愛河水上游 B.O.D.值為 0.0468 mM，中游 B.O.D.值為 0.0414mM，下游 B.O.D.值為 0.0369mM，出海口 B.O.D.值為 0.0300mM

柒、討論

一、【實驗一】
（一）本實驗將IC電路板、自製氣壓感測器、充電電瓶與三用電表連接，組裝成不同應用性的裝置，主要考慮的因素有：
  1.容器：考慮實驗過程中的壓力變化、溫度變化、溶劑性質、導熱性、鑽孔與否，選用不同材質的容器
  2.組裝：搭配不同實驗儀器的使用，設計不同的裝置方式，例如：開關位置、自製氣壓量測器與密閉系統的連接處、鐵架固定方式
  3.自製氣壓量測器的安裝：由於自製氣壓量測器需由其兩端壓力差，造成電阻(電壓)值的變化，所以需將量測儀器兩端分別接於待測壓力系統與另一已知的壓力環境，實際應用上將一端連通於大氣做為比較值，以便於計算出實際待測壓力值。
（二）歸納儀器本身有以下的一些優點：
  1.使用材料裝置簡單、便宜、易取得。
  2.實驗裝置如三通閥、鐵架、針筒，均為現成，不須精細製作即可使用。
  3.操作容易，所得數據精確。
  4.根據原理自行創意組裝，具有原創性。
（三）本儀器尚存的改進空間：
  1.測量電壓變化時可利用更小的測量單位，或利用加大電壓等方法，可量得更精確的氣壓變化值。
  2.改用更精巧的IC電路板，可以組裝出機動性更高的裝置，使測量更便利。

二、【實驗二】
（一）由測量所得的檢量線數據穩定，可證明此儀器的可靠性及穩定性。
（二）在固定電瓶電壓下(12.30V)，製作的檢減量線如(表2-6)，電瓶電壓愈大則相同氣壓差在檢量線上所對應的電阻值愈大。
（三）由實驗結果可知，氣壓差與電壓值成正比關係，並證明兩端氣壓差之大小關係將表現在電壓值的正負上，即量測器兩端連結氣壓環境互換時，所得之電壓值與原狀況下等值異號。
（四）由儀器可測得氣體的壓力外，亦可測液體的蒸氣壓，但測量蒸氣壓時須避免測量具有腐蝕性的液體，以免液體蒸氣對電阻膜造成損害，降低儀器的準確度。

三、【實驗三】
（一）由實驗知，溫度在26.3℃時，純水的蒸氣壓實驗值為22.61mmHg，而純酒精的蒸氣壓實驗值為53.45mmHg
（二）由改變液體混合比例的實驗可得知，所測得的蒸氣壓即為各液體飽和蒸氣壓乘以其莫耳分律之和。

四、【實驗四】
（一）由改變溫度的實驗可得知，溫度上升，液體蒸氣壓會變大，壓力的變化率也較大。
（二）不同液體蒸氣壓對單位溫度增加的改變量也各不相同。
（三）在選用不因壓力產生形變的容器條件下，以導熱性佳的材質使熱量能快速的傳導，蒸氣

五、【實驗五】
（一）由實驗結果驗證難溶性氣體較符合亨利定律，氧氣相對於二氧化碳較符合。

（二）前後壓力差增加則可增加溶解度變化量，爲壓力須在容器可承受之範圍內。

（三）由不同的溶劑或氣體進行實驗，可由氣體分壓變化與溶解度變化的關係求出各組待入亨利定律中的 k 值。

六、【實驗六】

（一）實驗操作時先以排水集氣法注入氧氣，再加壓至初始壓力後再注入河水，可減少氧氣與河水接觸時間，降低實驗誤差。

（二）測量溶氧量時，分別測已震盪及未震盪河水氧氣壓力的變化量相互比較可得原溶液的最初溶氧量，採用間接的方式求得河水溶氧量，若直接測量河水受震盪時的壓力變化，來推算溶氧量，因壓力變化可能源自氧氣之外其他溶於河水中的氣體，易有誤差，故以間接法求得。

七、由於數據較多，計算比對較多，所以我們學習使用 Excel 及 Windows-Word，使我們對電腦產生莫大的興趣。

捌、研究結論

經過這次的實驗，我們不僅獲得許多重要的實驗結論，同時我們的實驗基本步驟更臻純熟以及實驗相關的基本概念更清楚，實驗報告撰寫的邏輯更加清晰，更培養了我們許多正確的實驗態度。

一、自製一可測量蒸氣壓的『簡易』儀器，雖然經過了多次改良修正，但比起以一般方法來測量，我們不僅節省了需要購買水銀的經費，也避免使用水銀的高危險性，較以往簡易很多，亦得到合乎水準的實驗數據。

二、本實驗探討了有關氣體壓力、蒸氣壓與氣體溶解度的各項性質，驗證了拉午耳定律、亨利定律，並且透過親自操作，讓我們發現，其實科學研究不一定需要昂貴的儀器，自己動腦思考，也可以解決所遭遇的難題。

三、我們經由實驗與探索的過程，學到了做科學研究的方法及動腦思考的樂趣。

四、本組在後續的研究中，將繼續對於這套自製的氣壓量測裝置進行改良，希望能利用介面將其接到電腦中，並將其加以推廣於各種氣體壓力的測量、測定污水溶氧量及其他氣體性質的探討上，以求其應用性能更盡善盡美。

玖、參考文獻

一、網路資料關鍵字：IC 電路板

http://www.etc.org.tw/etc/Journal/61/icemitest.htm

二、網路資料關鍵字：拉午耳定律、亨利定律

http://general.chemistry.pu.edu.tw/henry/

http://wcc.as.ntu.edu.tw/cloud/ex1.html

三、高級中學物質科學化學篇(下). 龍騰文化事業公司主編. 民國95年3月出版

四、高級中學化學（上冊），泰宇出版社

五、卓靜哲等著，物理化學，台北：三民出版社，1997

六、田福助等編譯，物理化學，高立圖書有限公司，1999

七、CRC handbook of chemistry and physics U.S.A.：CRC Press 1999

八、IRAN、LEVINE，PHYSICAL、CHEMISTRY，McGraw-Hill，Inc，New York，1987

Examination of Pressure Related Properties Using a Simple Homemade Device

Contents

I. Introduction

1. Motives

The senior high school chemistry textbooks cover a number of contents discussing air pressure and its related theory and law, which arouses our interest in undertaking study and actual proof, only to find out that we cannot use an easy, accessible equipment to undertake the experiment regarding vapor pressure. Therefore, we develop the following research, hoping to design an easy method and instrument to deeply explore the contents about vapor pressure in the textbook.

Due to the flourishing development of electronic technology in recent years, the electronic circuit is widely applied to every field. In view of this and our interest in discussing the electronic circuit further, we hope that we can understand its principle and applicability, and at the same time search for a proper and feasible method of a non-commercial simple IC PCB that can measure vapor pressure accurately. And further it is properly applied to our experiment.

Apart from the curricular theories, our daily life is closely related to air. There are still many directions worth exploring. Therefore, we hope to combine its applicability with life and expand its applicable range to increase our knowledge and understanding of ambient surroundings.

2. Purpose

a. To assemble a simple gauge that can inspect and measure vapor pressure and fabricate its calibration curve.

b. To examine and prove Raoul's Law, and discuss the connection of vapor pressure from mixture liquid of different ratios.

c. To gain the value of vapor heat(ΔH) by using the liquid pure substance whose vapor pressure is acquired under different temperatures.

d. To examine and prove Henry's Law, and discuss the connection between the solubility of different vapors and their partial pressure.

e. Devise a simple method coupled with the non-commercial gauges to measure the B.O.D. values of water from the Kaohsiung Love River.

f. To examine the theory in the textbook by using non-commercial gauges, and further expand its applicability to the measurement of other vapor pressure laws.

This research is aimed to make an in-depth exploration into Raoul's Law and Henry's Law by using an accurate but simple vapor pressure gauge. The gauge is constructed from non-complicated electronic components- electronic IC PCB, film resistor, digital multi-meter, and battery.

In the first step, we measured the vapor pressure of six kinds of liquids and 3 liquid mixtures-water, ethanol, chloroform, acetone, benzene, toluene, mixture of water and ethanol, mixture of chloroform and acetone, mixture benzene and toluene. From the results of this experiments, the vapor pressures of water and ethanol liquid mixture, and chloroform and acetone liquid mixture were slightly lower than their theoretic values-called negative deviation solution,

while the vapor pressure of the benzene and toluene liquid mixture was quite close to its theoretic value-near an ideal solution.

In the second step, the individual vapor pressures of water, ethanol, and chloroform were measured at various temperatures; the vapor heat(ΔH) were calculated by using the lausius-Clapeyron equation.
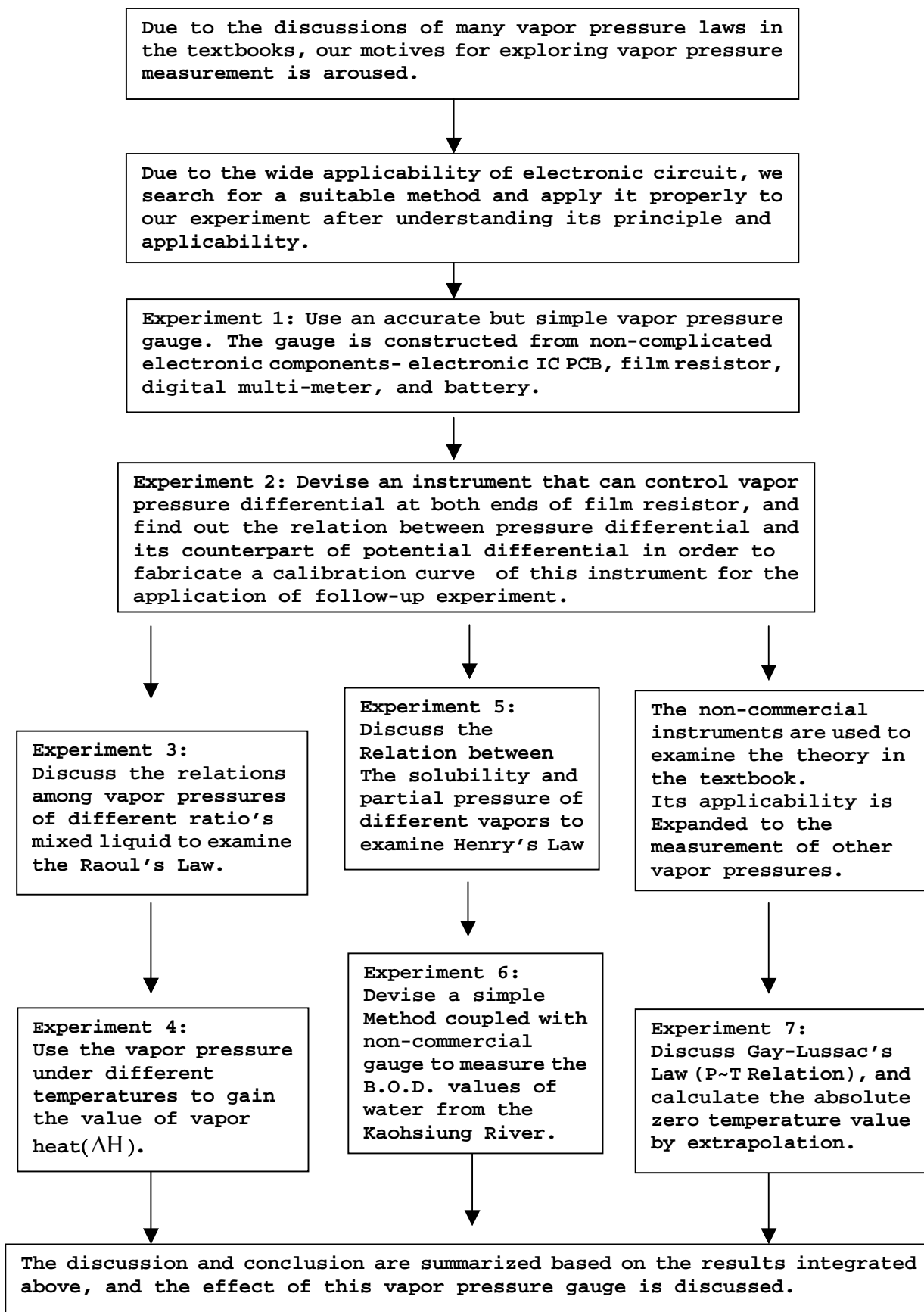
In the final step, we used the gauge and other non-commercial instruments to measure the B.O.D. values of water from the Kaohsiung Love River, found the P-T correlation using Gay-Lussac's Law, and calculated the absolute zero temperature value by extrapolation.

II. Materials and Methods

(1)Materials				
AB Adhesives	Thermoplastics	Tin	Welding Gun	Adhesive Tape
Triple Valves	Syringe（25、60mL）	Straws	Hose	T Tube
(2)Equipment				
Film Resistor	IC PCB	Multi-meter	Crocodile Clip	Battery (12V)
Air Pump	DC Supplies	Thermostatic Bath	Ultrasonic Oscillator(Remove vapor in the water)	
(3)Equipment				
Erlenmeyer Flask	Plastic Bottle	Acrylic Cup	CO2 Cylinder	Oxygen Cylinder
Nitrogen Cylinder	Beaker	Thermometer	Electronic Balance（AND HF-400）	
Plastic Dropper	Plastic Pipe	Double Wall Mug		
(4)Medicines				
Distilled Water	Absolute Alcohol	Toluene	Benzene	Chloroform
Acetone	Soapy Water(Used for checking if there is air leakage)			

Procedures and Methods

Experiment Flow：

Due to the discussions of many vapor pressure laws in the textbooks, our motives for exploring vapor pressure measurement is aroused.

Due to the wide applicability of electronic circuit, we search for a suitable method and apply it properly to our experiment after understanding its principle and applicability.

Experiment 1: Use an accurate but simple vapor pressure gauge. The gauge is constructed from non-complicated electronic components- electronic IC PCB, film resistor, digital multi-meter, and battery.

Experiment 2: Devise an instrument that can control vapor pressure differential at both ends of film resistor, and find out the relation between pressure differential and its counterpart of potential differential in order to fabricate a calibration curve of this instrument for the application of follow-up experiment.

Experiment 3:
Discuss the relations among vapor pressures of different ratio's mixed liquid to examine the Raoul's Law.

Experiment 5:
Discuss the Relation between The solubility and partial pressure of different vapors to examine Henry's Law

The non-commercial instruments are used to examine the theory in the textbook. Its applicability is Expanded to the measurement of other vapor pressures.

Experiment 4:
Use the vapor pressure under different temperatures to gain the value of vapor heat(ΔH).

Experiment 6:
Devise a simple Method coupled with non-commercial gauge to measure the B.O.D. values of water from the Kaohsiung River.

Experiment 7:
Discuss Gay-Lussac's Law (P~T Relation), and calculate the absolute zero temperature value by extrapolation.

The discussion and conclusion are summarized based on the results integrated above, and the effect of this vapor pressure gauge is discussed.

【Experiment 1】Assemble an accurate, simple vapor pressure gauge.

1. Experiment Device:

　　Use simple, inexpensive parts and electronic components to assemble an instrument that can measure vapor pressure.

Fig.1 Pressure gauge is positioned on a PC board

2. Gauge Device:

　(1) The film resistor is attached to electronic IC PCB. The vapor pressure differential measured at both ends is expressed in the voltage change of film resistor.

　(2) The both sides of film resistors are respectively connected with different pressure systems: one is connected with atmosphere; the other connected with the pressure system expected to be measured.

　(3) The electronic PCB is connected with battery and multi-meter. The calibration curve is fabricated for vapor pressure and voltage, reading voltage so that the vapor pressure expected to be measured can be known.

　(4) Different measurement instruments are devised based on the different requirements of pressure surroundings expected to be measured.

　　a.　As shown in Table 1-1, an accurate but simple vapor pressuregauge is assembled by using electronic components- electronic IC PCB, film resistor, digital multi-meter, and battery.

Fig.1-1

　　b.　Experiment II: make an experiment device to alter the voltage differential at the both ends of film resistor. Find out the relation between pressure differential and its counterpart of potential differential. The calibration curve of this gauge is fabricated for the application of follow-up experiment.

　　c.　Experiment III: make an experiment device to discuss the relation between vapor pressure and mixed liquid to examine Raoul'ts Law.

Fig.1-2

　　d.　Experiment IV: make an experiment device to extrapolate the vapor heat(∆H) of liquid pure substance.

　　e.　Experiment V: make an experiment device and discuss the relation between the solubility and partial pressure of different vapors to examine Henry's Law
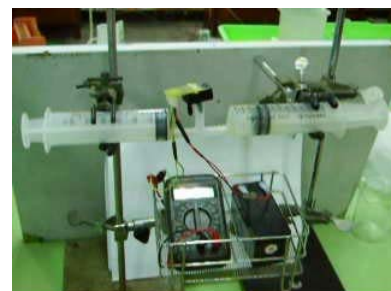

Fig.1-3

Fig.1-4

Fig.1-5

f. Experiment VI: devise a simple method coupled with non-commercial gauge to measure the B.O.D values of water from Kaohsiung River.

.

Fig.1-6

Fig.1-7

Fig.1-8

Fig.1-9

【Experiment 2】 The Fabricated Gauge's Vapor Pressure Differential and the Voltage's Calibration Curve

1. Device: Connect to an air pump, control the pressure differential on both ends of film resistor, record the changes of voltage value to be the calibration curve of this gauge.

Manipulation Variable	Pressure differential on both ends of film resistor
Controlling Variable	Total resistance of circuit, battery's voltage, conical flask's capacity

2. Steps:
   (1) The film resistor is connected to the conical flask, then the lateral tube is connected to air pump. The air pump is connected to the other end of conical flask. Control the pressure surrounding of conical flask, which is controlled by a switch. The gauge and the conical flask form a closed surrounding.
   (2) Use the air pump to pump up the pressure in the conical flask to be a minimum value (The readings on the barometer for the is comparative to the atmosphere pressure-710mmHg).Then read the voltage value. Use the switch to control the vapor pressure until it gradually rises to an atmosphere pressure. In the process, control the pressure interval at 50mmHg and read the voltage values for different pressures. Make observations and note down both relations.
   (3) Repeat the above procedure and record the relation between different pressure differentials and voltage. Every experiment is done three times. Then take the average value to make the calibration curve for the vapor pressure gauge.
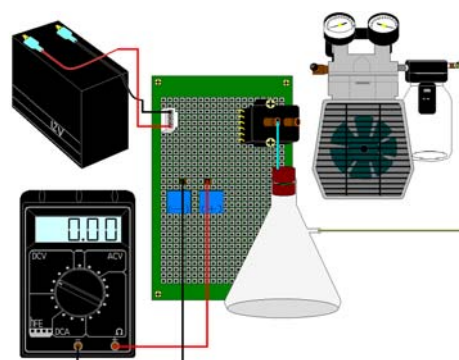

Fig.2-1

【Experiment 3】 Make Use of the Gauge to Discuss Raoul's Law and Relation of Positive and Negative Deviation for Solution Vapor Pressure

1. Device: We decide to use the gauge coupled with pressure quantity sensor to measure pure solvent, pure solute and vapor pressure of two components' mixed solution, and make observations to find their relation.

Manipulation Variable	Type of solution and ratio of mixture.
Controlling Variable	Vapor chamber's volume, temperature, total resistance of circuit, battery's voltage

2. Steps:

(1) Use a syringe to take out the volume of mixed solution expected to be measured.
(2) Put the syringe containing liquid to be measured on the left side, and put one empty syringe on the right side to be respectively connected to both sides of T tube.
(3) The top of T tube is connected to the vapor pressure gauge.
(4) Push the liquid in the left syringe into T tube slowly. At the same time, use the right syringe to pump the liquid in the T tube until nothing remains in it.
(5) Observe the vapor pressure change in the T tube before and after dropping the liquid. The vapor pressure change measured is the liquid saturated vapor pressure value under this temperature.
(6) Measure the voltage in this experiment gauge. The obtained voltage value can get the vapor pressure value according to the calibration curve in experiment II.
(7) There will be a change in the solution's temperature after mixture. Therefore, we will wait for some time until the pressure becomes balanced and stable, then measure the vapor pressure(Use one control group. After mixing in the atmosphere at the same ratio, measure with a thermometer to be the room temperature.
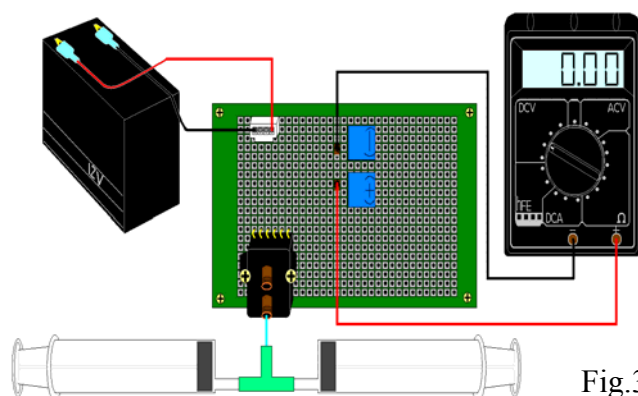
Fig.3-1

【Experiment 4】Make Use of Non-Commercial Gauge to Extrapolate the Vapor heat(ΔH) of liquid pure substance

1.Device: Make use of this gauge coupled with pressure gauge to measure the vapor pressure of liquid pure substance under different temperatures. And make use of clausius-clapeyron equation to extrapolate vapor heat(ΔH)

Manipulation Variable	Pure substance liquid's temperature, pure substance liquid's type
Controlling Variable	Pure substance liquid's volume, total resistance of circuit, battery's voltage, plastic bottle's capacity

2.Steps:

(1) Heat up the liquid in the beaker to an initial temperature $30℃$. Pour it into plastic bottle, and open the triple valves to make inside and outside pressure consistent.

(2) Seal with a cork and connect to vapor pressure gauge, and close triple valves.

(3) Put plastic bottle in thermostatic bath. Change the temperature in thermostatic bath until balanced. Measure the vapor pressure with pressure gauge, and read the readings on the thermometer.

(4) Repeat step 1,2,3, and measure the vapor pressure values under different temperatures.

(5) Undertake the above steps with water, alcohol and acetone. Record the relation between pressure and temperature.

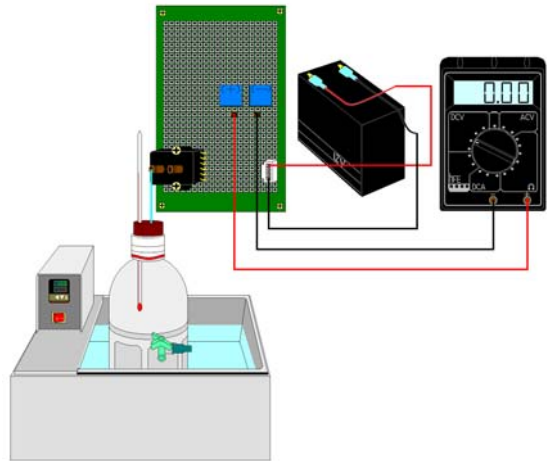(6) Every pure substance liquid is experimented three times, then take the average value.

Fig.4-1

[Experiment 5] Exploration of Henry's Law and the Correlation between partial pressure and dissolution degree of different gases

1. Design: To utilize this pressure measuring instrument to design experiment device, in order to probe into the correlation between dissolution degree and partial pressure of different gases to verify Henry's Law.

Independent Variables	Partial pressure of gas to be measured and types of gases
Controlling Variables	The acrylic cup volume, temperature, dissolvent quantity, gas chamber volume, recruit total resistance, and battery voltage

2. Research Procedure:

(1) Ideas and mathematics formula proving:

a. Ideas:

To associate with the Henry's Law, $m = kp$ (m: gas dissolution degree under water, p: gas pressure, k: constants) stating on high school books from the phenomenon of gas escaping while opening the soda cap, and infer that $\Delta m = k\Delta p$ from this formula; as a result, the constant k of Henry's Law could be acquired from Δm, Δp.
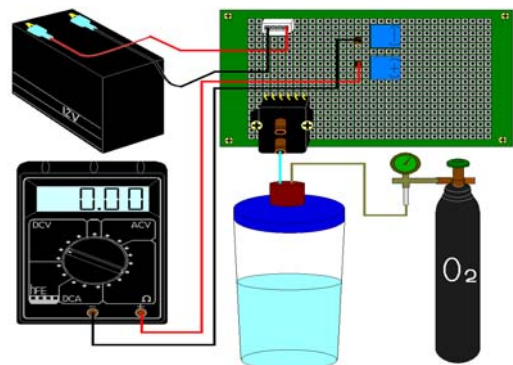

Fig.5-1

9

b. Mathematics formula proving:

P_i : Initial Pressure (saturation) P_f: End Pressure (new balance status) V_g: Gas Volume V_e: Water Solution Volume Δm: Dissolution Degree Variation Δp: Gas Pressure Difference of Super-Saturation Status and New Balance Status

$\Delta m = \Delta n / V_e = k(P_i - P_f)$

And further utilize the ideal gas formula $PV = nRT$ to obtain

$\Delta n = \Delta P \cdot V_g / R \cdot T$, from which k could be calculated

c. Experiment Procedure and Skills

First of all, to produce a saturation to read the pressure P_i under this balance status and then leak gas to produce super-saturation status. Because of gas leaks too soon in the first experiment which resulted in gas under water escaping swiftly, so the dissolution degree variation Δm_l can't be ascertained. After improvement, extremely slow gas relief method is adopted to avoid gas escaping in a great quantity and successfully produce super-saturation P_{n1}. And to shake to make gas escape to reach a new balance status P_{f1}, and keep doing so, and then slowly leak to acquire P_{n2}, shake to acquire P_{f2}… a k could be obtained in each stage, and average k value could be calculated through graphing by m, P.

In this way, not only the formula can be made one but to read P_i as above stated and P_{ni} of every stage, k of every stage could be acquired through P_{f1} and gain the most exact value of k. The above is the method of pressure declination to acquire k. If want to acquire k through pressure rise; in the same way, we only have shake the non-saturated pressure P_{ni} to obtain the balance pressure P_{fi} after shaking, and Δm could be gained through utilizing the value of $\left| P_n - P_f \right|$.

3. Steps:

(1) Connect the bottle to pressure measuring instrument, and infuse water into bottle.

(2) Add the gas to be measured through the method of collection process with displacement of water to read V_i reading of multimeter.

(3) Extract air by syringe to make pressure within bottle decreases slowly and read V_n reading at this moment.

(4) Shake the bottle body to make the super-saturated gas escape and read V_f after balancing.

(5) Record different Δm under repeating different ΔP. (perform experiments three times and calculate the average value)

Convert into ΔP from $(V_f - V_i)$- ①

Convert into ΔPm from $(V_f - V_n)$, and substitute into $\Delta PmV = \Delta nRT$ to acquire Δm -②

Substitute into $\Delta m = k \cdot \Delta P$ by ① 、 ② to obtain k

[Experiment 6] Utilize Pressure Measuring Instrument to Measure B.O.D. Value of Kaohsiung River Water Quality

1. Experiment Design: Design simple method with self-made instrument to determine the B.O.D. value (Biochemical Oxygen Demand) of Love Kauhsiung River water quality in upstream, middle-course, downstream and outlet.

Independent Variables	Different river water of river section (upstream, middle-course, downstream and outlet)
Controlling Variables	Temperature, oxygen partial pressure, river water quantity to be measured, gas chamber volume, circuit total resistance, battery voltage, and bottle volume

2. Steps:

(1) Take water from each river section and use ultrasonic oven to make gas dissolved within totally escape.

(2) Pour O_2 into bottle by method of collection process with displacement of water, and then continuously infuse O_2 after water totally drained out.

(3) And then use the syringe rapidly infuses into river water to be measured, and read the reading P_1 (V_1) of air pressure measuring instrument at this moment.

Fig.6-1

(4) Wait till the dissolution balanced, read $P_2(V_2)$ at this moment, and convert ΔPm from (V_2-V_1), and then substitute into $\Delta PmV = \Delta nRT$ to obtain the maximum value m_0 of soluble O_2 in river water.

(5) And then take river water (non-shaking) to repeat step 2, 3, readings P_3, P_4, to convert ΔPm from $(V_4 - V_3)$ and substitute into $\Delta PmV = \Delta nRT$ to obtain the additional soluble O_2 quantity Δm of original river water.

(6) Let $m_0 - \Delta m = m$, that is the soluble O_2 quantity of river water. m_0: The greatest dissolved oxygen quantity of river water. PS.: Soluble O_2 quantity could be conjectured from the degree of Δm, but m_0 of different river sections might be various.
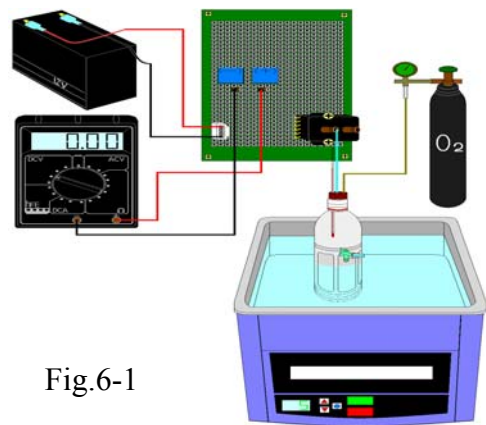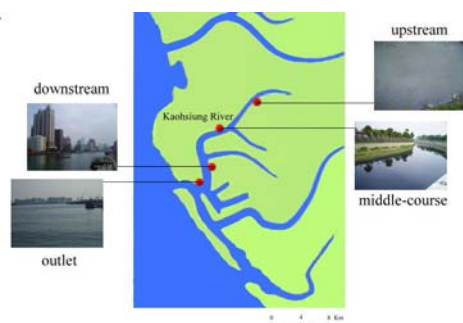

Fig.6-2

Fig.6-3

III. Result

1. In Experiment 2, the correlation between pressure and voltage in the manufactured calibration curve, the R^2 value between the two is found to be up to 0.9997, the linear relationship of the whole graph is $y = 1.9886x - 2.7875$, the inaccuracy value of measurement is 0.12% in average, the maximum inaccuracy value is 2%, the minimum one is 0.17% (the above mentioned doesn't include 50mmHg). This means that the instruments we used exhibit a linear correlation on measuring the variation of air vapor pressure, and has very high positive correlation, so it's suitable to measure the pressure changes within the containers.

Data and Relationship Diagram:

Pressure difference (mmHg)	760.00	710.00	660.00	610.00	560.00
Pressure in (mmHg)	0.00	50.00	100.00	150.00	200.00
Voltage (0.001V)	0.00	28.40	51.60	75.23	103.54
Pressure differenc(mmHg)	510.00	460.00	410.00	360.00	310.00
(mmHg)	250.00	300.00	350.00	400.00	500.00
Voltage (0.001V)	125.43	153.30	178.40	203.52	251.20
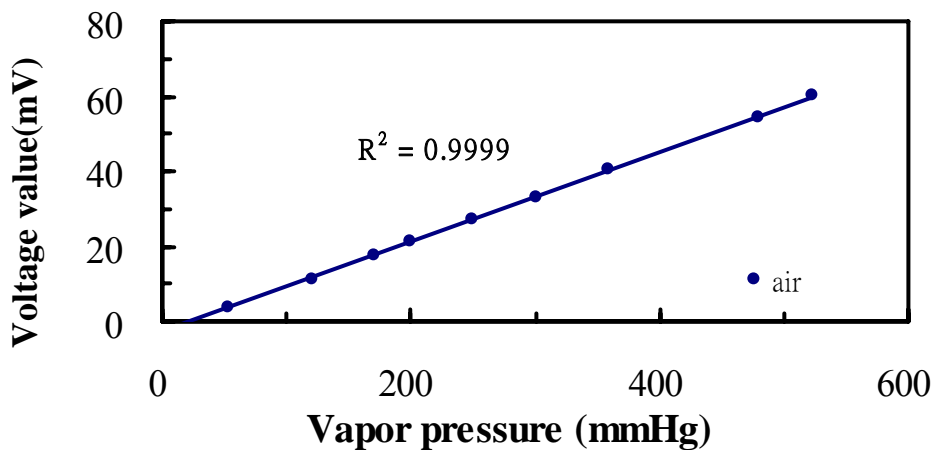
Fig.1-1
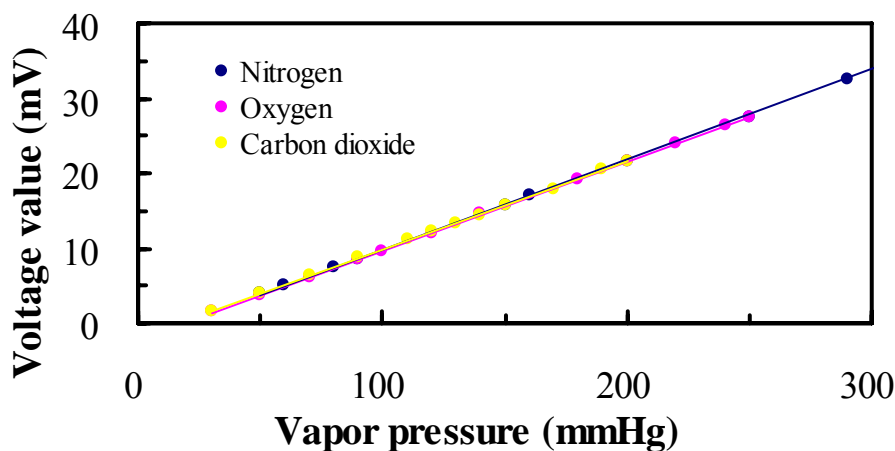
Fig.1-2

	air	O2	N2	CO2
slope	0.120	0.118	0.120	0.117
Deviation from air curve	-	1.33%	0.25%	2.17%

Table.1-1

(1)Use an air pump to control the pressure changes for the whole system with our gauge. Use voltage to measure the pressure value of system. It is found that the R^2 between the two reaches 0.9997. The linear relation is y=1.9886x-2.7875.The average differential value is 0.12%.The maximum differential value is 2%, and the minimum is 0.17%(the above does not include 50mmHg).This shows that the gauge we use for measuring the air pressure change presents a good linear relation. There is a highly positive correlation, so it is very suitable for measuring the pressure change in the container.

(2)The use of this gauge can easily and quickly measure the pressure value. The use of high linear relation can accurately and correctly measure the experiment data for the benefit of data management and promotion to the related experiments of other vapors.

2. In Experiment 3, because water and alcohol both possess intermolecular hydrogen bonding and both of they are polar molecules, so the mutual solubility is quite good. However, the combination between molecules is higher than the original molecules', so the negative deviation would be formed after mixing. When the difference of mole fraction is greater (close to dilute solution), the deviation is much more unobvious. The experiment result of acetone and chloroform is the same with that of water and alcohol in general. In the experiment of benzene and toluene, due to the distance of gravity between the two is not great, the experiment obviously shows that the result of the mixing of the two still shows little portion of negative deviation. But it's much smaller compared to the deviation condition of water and alcohol, and acetone and chloroform, so it could still reason to the ideal solution condition effectively.

Data and Analysis

(1) Water and Ethanol (T=26.3℃)

water (mole fraction)	ethanol (mole fraction)	voltage (0.01V)	vapor pressure of the mixture (mmHg)	ideal vapor pressure of the mixture (mmHg)	ideal vapor pressure of ethanol (mmHg)	ideal vapor pressure of water (mmHg)
1.00	0.00	12.77	22.61	22.61	0.00	22.61
0.90	0.10	13.12	23.31	25.74	5.35	20.39
0.80	0.20	13.94	24.94	28.78	10.69	18.09
0.70	0.30	14.99	27.03	31.87	16.04	15.83
0.60	0.40	16.13	29.29	34.95	21.38	13.57
0.50	0.50	17.18	31.73	38.04	26.73	11.31
0.40	0.60	19.43	35.86	41.11	32.07	9.04
0.30	0.70	21.68	40.33	44.20	37.42	6.78
0.20	0.80	24.15	45.23	47.28	42.76	4.52
0.10	0.90	26.27	49.46	50.37	48.11	2.26
0.00	1.00	28.28	53.45	53.45	53.45	0.00

Table2-1
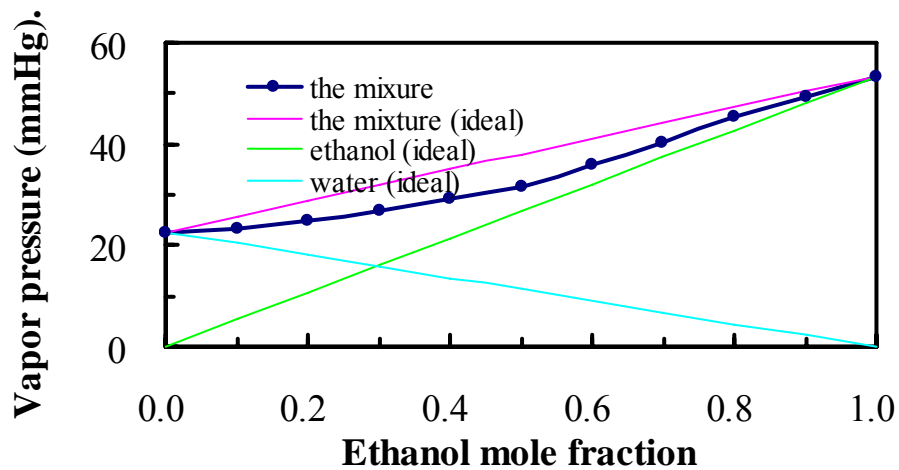
Fig.2-1

(2) Acetone and Chloroform (T=25.9℃)

acetone (mole fraction)	chloroform (mole fraction))	voltage (0.01V)	vapor pressure of the mixture (mmHg)	deal vapor pressure of the mixture (mmHg)	ideal vapor pressure of ethanol (mmHg)	ideal vapor pressure of water (mmHg)
1.00	0.00	121.96	239.74	239.74	239.74	0.00
0.90	0.10	115.86	227.62	237.00	215.77	21.23
0.80	0.20	112.68	221.29	234.26	191.79	42.47
0.70	0.30	107.74	211.46	231.52	167.82	63.70
0.60	0.40	105.59	207.19	228.78	143.84	84.94
0.50	0.50	102.64	201.33	226.04	119.87	106.17
0.40	0.60	103.69	203.42	223.30	95.90	127.40
0.30	0.70	105.91	207.82	220.56	71.92	148.64
0.20	0.80	107.11	210.21	217.82	47.95	169.87
0.10	0.90	106.58	209.15	215.08	23.97	191.11
0.00	1.00	108.18	212.34	212.34	0.00	212.34

Table2-2

Fig.2-2

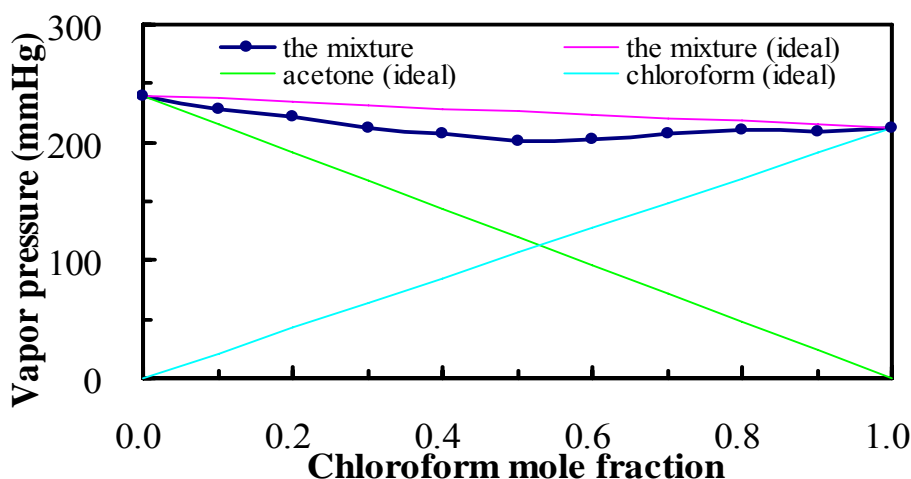(1) From the experiment data, it can be inferred that water and alcohol have intermolecular hydrogen bonding, and that both are polarity molecules and have good dissolvability. The molecules are not likely to separate and reduce the original vapor pressure. However, the intermolecular binding is stronger than the original molecules. So, the negative deviation occurs after mixture.

(2) From the graph, it can be found that when two molecules' mole fraction are closer, the deviation is even clearer. And when the mole fraction difference is greater (close to thin solution), the deviation is not clear. The experiment result of Chloroform and acetone is much similar to that of water and alcohol.

(3) In the experiment of benzene and toluene, the attraction between the two cannot be ignored because there is not too much gap between both attractions. There is still deviation.The experiment shows that there is a partial negative deviation after the two are mixed. But compared to water, alcohol, chloroform and acetone, the deviation is smaller. So it can be extrapolated to be an ideal solution.

(4) According to the above experiment result, from the gauge's method and principle, the experiment data and related examples that have negative deviation experiment data can be inferred. So the gauge has considerable accuracy, and can be applied to experiment with negative deviation result.

3. In Experiment 4, the vaporization heat of water, ethanol, and acetone respectively from clausius-clapeyron equation are calculated by using the experimental value of temperature and vapor pressure and state as the following: water 9626.52 (cal/mole), ethanol 8911.7 (cal/mole) and acetone 7183 (cal/mole). The experimental and theoretical value of this experiment doesn't have great difference, the inaccuracy value is under 1% in average. II.

Data and Analysis

(1) Water

t (℃)	T(k)	P(water)mmHg	1/T	logP(water)
55.00	328.00	121.65	0.0030	2.09
50.00	323.00	92.95	0.0031	1.97
40.00	313.00	55.14	0.0032	1.74
30.00	303.00	31.53	0.0033	1.50

Table3-1

(2) Ethanol

t(℃)	T(k)	P(ethanol)mmHg	1/T	logP(ethanol)
55.00	328.00	202.27	0.0030	2.31
50.00	323.00	172.71	0.0031	2.24
40.00	313.00	123.15	0.0032	2.09
30.00	303.00	84.32	0.0033	1.93

Table3-2

(3) Acetone

t(℃)	T(k)	P(acetone)mmHg	1/T	logP(acetone)
55.00	328.00	844.27	0.0030	2.93
50.00	323.00	672.71	0.0031	2.83
40.00	313.0	463.15	0.0032	2.67
30.00	303.00	337.42	0.0033	2.53

Table3-3
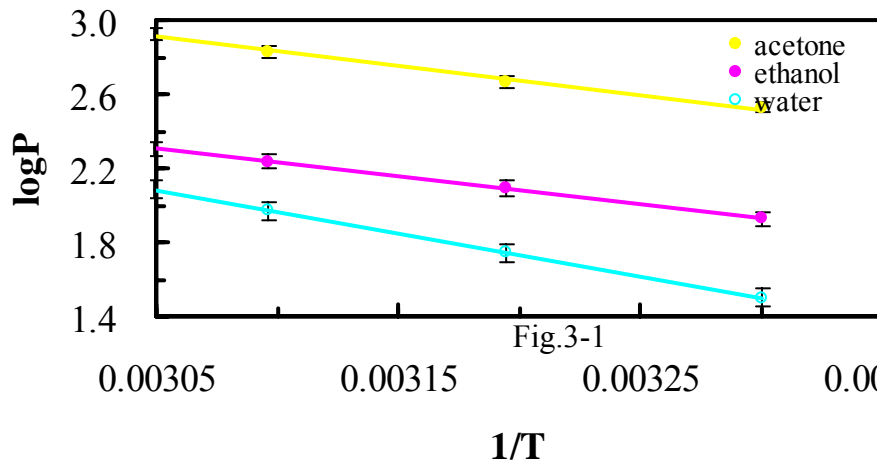
Fig.3-1

(1) The container will be easily deformed when heated up to 60℃, which results in inaccuracy. So the highest temperature in the experiment is 55℃.

(2) Because it is not easy for thermostatic bath to reach heat symmetry in the course of heating the liquid. After improvement, the bottle is equipped by a thermometer so that the water temperature in the bottle can be measured more accurately.

(3) The pressure value starts to be measured at 30℃. Then continue to heat up, and measure the pressure change. The air pressure can be corrected from $P_1/T_1=P_2/T_2$, and the liquid's vapor pressure is calculated.

(4) At the moment of heating, the pressure increases, which results in the rise of vapor's dissolvability. So the vapor pressure measured by the gauge shall be smaller than the actual value after the element of air pressure inflation is eliminated.

(5) The vapor heat is calculated from clausius-clapeyron equation. (as Table 4-4)

enthalpy of vaporization (cal/mole)	Obtained value	theoretic value
wather	9626.5	9737
ethanol	8911.7	9222
acetone	7183.0	7488

Table3-4

4. In Experiment 5, the average k value of CO_2 and O_2, CO_2 : 2.63×10^{-2} mM, O_2: 4.34×10^{-3} mM. The correlation of k value of CO_2 and O_2 towards pressure is that k value of CO_2 exhibits positive deviation while pressure is great, from which it could be derived that Henry's Law is applied to conditions of low temperature, pressure and poorly water soluble gases. The dissolution degree of O_2 and the oxygen pressure is in direct proportion, from which Henry's Law could be proved.

Statistics & Analysis

Gas: CO_2 Temperature = 23.4℃

(Figuring out the air pressure value P through the voltage V from experiment statistics) (- stands for smaller than a unit of atmospheric pressure.)

	1			2		
temperature(℃)	23.4	23.4	23.4	23.4	23.4	23.4
volume of gas(mL)	101.00	101.00	101.00	101.00	101.00	101.00
volume of solution(mL)	55.40	55.40	55.40	55.40	55.40	55.40
V_i(V)	0.035	0.031	0.019	0.013	0.009	0.002
P_i(mmHg)	826.81	818.85	794.99	783.06	775.10	761.18
V_n(V)	0.030	0.016	0.011	0.008	0.000	-0.002
P_n(mmHg)	816.87	788.63	779.57	772.922	757.21	753.65
V_f(V)	0.031	0.019	0.013	0.009	0.002	-0.001
P_f(mmHg)	818.85	794.99	783.06	775.10	761.18	755.23

Table4-1

	3			4		
temperature(℃)	23.3	23.3	23.3	23.3	23.3	23.3
volume of gas(mL)	101.00	101.00	101.00	101.00	101.00	101.00
volume of solution(mL)	5450	55.40	55.40	50.50	50.50	50.50
V_i(V)	0.005	-0.001	-0.003	0.025	0.017	0.011
P_i(mmHg)	767.15	755.23	751.25	806.92	791.01	779.08
V_n(V)	0.000	-0.004	-0.007	0.015	0.010	0.03
P_n(mmHg)	757.21	749.27	741.31	787.03	776.29	764.03
V_f(V)	0.001	-0.003	-0.007	0.017	0.011	0.005
P_f(mmHg)	759.20	751.25	743.30	791.01	779.08	767.15

Table4-2

Gas: O_2 Temperature = 23.2℃ (- stands for smaller than a unit of atmospheric pressure.)

	1			2		
temperature(℃)	24.0	24.0	24.0	24.0	24.0	23.9
volume of gas(mL)	137.6	137.6	137.6	137.6	137.6	137.6
volume of solution(mL)	18.8	18.8	18.8	18.8	18.8	18.8
V_i(V)	0.046	0.037	0.030	0.027	0.004	0.019
P_i(mmHg)	848.68	830.78	816.86	810.90	765.16	794.99
V_n(V)	0.036	0.030	0.019	0.021	-0.003	0.004
P_n(mmHg)	828.79	816.68	794.74	798.84	751.09	764.88
V_f(V)	0.037	0.030	0.019	0.021	-0.003	0.004
P_f(mmHg)	833.57	816.86	794.99	798.97	751.25	765.16

Table4-3

	3			4		
temperature(℃)	23.9	23.9	23.9	22.8	22.8	22.8
volume of gas(mL)	105.4	105.4	105.4	126.6	126.6	126.6
volume of solution(mL)	51.0	51.0	51.0	29.8	29.8	29.8
V_i(V)	0.021	0.014	0.001	0.045	0.044	0.053
P_i(mmHg)	798.97	784.45	759.20	846.69	844.70	862.60
V_n(V)	0.013	0.001	-0.006	0.039	0.032	0.044
P_n(mmHg)	783.06	758.22	744.79	834.51	820.40	844.37
V_f(V)	0.014	0.001	-0.006	0.039	0.032	0.044
P_f(mmHg)	785.05	759.20	745.29	834.76	820.84	844.70

Table4-4

	5			6		
temperature(℃)	22.0	22.0	22.0	22.0	22.0	22.0
volume of gas(mL)	107.0	107.0	107.0	107.0	107.0	107.0
volume of solution(mL)	49.4	49.4	49.4	49.4	49.4	49.4
V_i(mV)	32.0	21.4	16.1	24.6	17.2	5.9
P_i(mmHg)	820.84	799.76	789.22	806.12	791.41	768.94
V_n(mV)	20.9	15.9	8.0	17.0	5.5	-9.5
P_n(mmHg)	798.97	788.82	773.12	791.01	768.14	738.33
V_f(mV)	21.4	16.1	8.1	17.2	5.9	-8.9
P_f(mmHg)	799.76	789.22	774.90	791.41	768.94	739.51

Table4-5

According to the methods above, determine the K values of different gases. $Pm=Pf-Pn$ $\Delta P=Pf-Pi$

K value of CO_2

|	1	2	3	4
gas	CO_2			
volume of gas(mL)	101.00	101.00	101.00	101.00
volume of solution(mL)	55.40	55.40	55.40	50.50
temperature (℃)	23.4	23.4	23.3	23.3
$P_{i\,1}$ (mmHg)	826.81	783.06	767.15	806.92
P_{n1} (mmHg)	816.87	772.922	757.21	787.03
P_{f1} (mmHg)	818.85	775.10	755.23	791.01
△P_1 (mmHg)	7.96	7.96	7.96	15.91
Pm_1 (mmHg)	1.98	2.178	1.99	3.98
Δm_1(mM))	0.1954	0.2140	0.1964	0.4310
k_1(mM/ mmHg)	2.45×10^{-2}	2.69×10^{-2}	2.46×10^{-2}	2.70×10^{-2}
P_{i2}(mmHg)	818.85	775.10	755.23	791.01
P_{n2}(mmHg)	788.63	757.21	750.26	776.29
P_{f2} (mmHg)	794.99	761.18	751.25	779.08
△P_2 (mmHg)	23.86	13.92	3.98	11.93
Pm_2 (mmHg)	6.36	3.97	0.99	2.786
Δm_2(mM))	0.6277	0.3918	0.0977	0.2961
k_2(mM/ mmHg)	2.65×10^{-2}	2.81×10^{-2}	2.45×10^{-2}	2.52×10^{-2}
P_{i3}(mmHg)	794.99	761.18	751.25	779.08
P_{n3}(mmHg)	779.57	753.65	741.31	764.03
P_{f3}(mmHg)	783.06	755.23	743.30	767.15
△P_3(mmHg)	11.93	5.95	7.95	11.93
Pm_3(mmHg)	3.49	1.58	1.99	3.12
Δm_3(mM)	0.3441	0.1556	0.1964	0.3448
k_3 (mM/ mmHg)	2.88×10^{-2}	2.62×10^{-2}	2.47×10^{-2}	2.89×10^{-2}
A: y-intercept	2.32×10^{-3}	2.32×10^{-3}	4.52×10^{-3}	3.85×10^{-3}
R-squared value	0.9999	0.9995	0.999	0.9996
K value	2.66×10^{-2}	2.71×10^{-2}	2.46×10^{-2}	2.70×10^{-2}

Table4-6
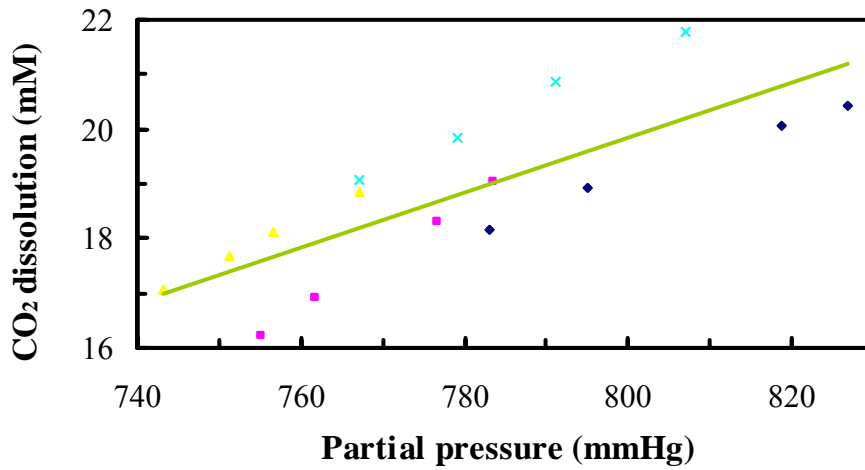
Fig.4-3

According to the methods above, determine the K values of different gases. $P_m = P_f - P_n$ $\Delta P = P_f - P_i$

K value of O_2

	一	二	三	四	五	六
gas	O_2					
volume of gas(mL)	137.6	137.6	105.4	126.6	107.0	107.0
volume of solution(mL)	18.8	18.8	51.0	29.8	49.4	49.4
temperature (℃)	24.0	24.0	23.9	22.8	22.0	22.0
P_{i1} (mmHg)	848.68	810.90	798.97	846.69	820.84	806.12
P_{n1} (mmHg)	833.41	798.84	784.45	834.51	798.97	791.01
P_{f1} (mmHg)	833.57	798.97	785.05	834.76	799.76	791.41
$\triangle P_1$ (mmHg)	15.11	11.93	13.92	11.93	21.08	14.71
P_{m1} (mmHg)	0.16	0.13	0.60	0.25	0.79	0.40
Δm_1(mM)	0.0630	00524	0.0666	0.0573	0.0930	0.0471
k_1(mM/ mmHg)	4.17×10^{-3}	4.39×10^{-3}	4.77×10^{-3}	4.80×10^{-3}	4.4×10^{-3}	3.2×10^{-3}
P_{i2}(mmHg)	830.78	765.16	785.05	844.70	799.76	791.41
P_{n2}(mmHg)	816.68	751.09	758.22	820.40	788.82	768.14
P_{f2} (mmHg)	816.86	751.25	759.20	820.84	789.22	768.94
$\triangle P_2$ (mmHg)	13.92	13.91	25.85	23.86	10.54	22.47
P_{m2} (mmHg)	0.18	0.16	0.98	0.44	0.40	0.80
Δm_2(mM)	0.0715	0.025	0.1111	0.1019	0.0471	0.0942
k_2(mM/ mmHg)	5.14×10^{-3}	4.68×10^{-3}	4.25×10^{-3}	4.32×10^{-3}	4.4×10^{-3}	4.1×10^{-3}

21

P_{i3}(mmHg)	816.86	794.99	759.20	862.60	789.22	768.94
P_{n3}(mmHg)	794.74	764.88	744.79	844.37	774.37	738.33
P_{f3}(mmHg)	794.99	765.16	745.29	844.70	774.90	739.51
$\triangle P_3$(mmHg)	21.87	29.83	13.91	17.90	14.32	29.43
P_{m3}(mmHg)	0.25	0.28	0.50	0.33	0.53	1.18
Δm_3(mM)	0.0983	0.1124	0.0555	0.0760	0.0629	0.1390
k_3(mM/ mmHg)	4.49×10^{-3}	3.76×10^{-3}	3.98×10^{-3}	4.23×10^{-3}	4.38×10^{-3}	4.6×10^{-3}
A: y-intercept	2.32×10^{-3}	2.32×10^{-3}	4.52×10^{-3}	3.85×10^{-3}	4.52×10^{-3}	3.85×10^{-3}
R-squared value	0.9999	0.9995	0.999	0.9996	0.999	0.9996
K value	4.60×10^{-3}	4.28×10^{-3}	4.33×10^{-3}	4.45×10^{-3}	4.39×10^{-3}	3.97×10^{-3}

Table4-7

K value of O_2
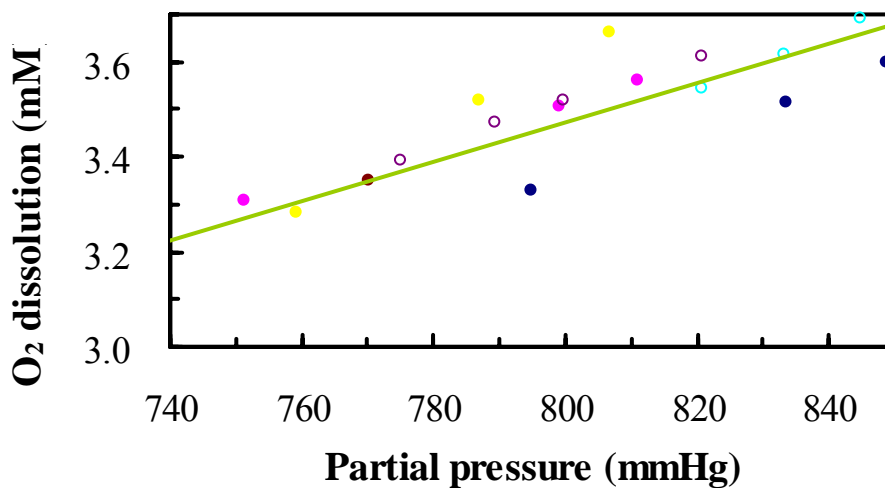
Fig.4-2

(1) The average k value of CO_2 and O_2 is: CO_2: 2.63×10^{-2} mM, O_2: 4.34×10^{-3}mM. Obtained the partial pressure of oxygen (CO_2) on the surface of water solution by this device, and the dissolution degree of this gas could be calculated.

(2) The correlation of value k of CO_2 and O_2 towards pressure is that: Value k of CO_2 shows positive deviation while pressure is great, from which it could be derived that Henry's Law is applied to poorly water soluble gas under the conditions of low temperature, pressure and poorly water soluble gases. The correlation between dissolution degree of O_2 and oxygen pressure is in direct proportion, from which Henry's Law could be proved.

5. In Experiment 6, the B.O.D. value in the upstream of Kaohsiung River is 0.0468 mM, in the middle-course is 0.0414 mM, in the downstream is 0.0369 mM, and in the outlet is 0.0300 mM.

Statistics & Analysis

※ Kaohsiung River Upstream　　　　Table5-1

		1	2	3	4
Volume of sample solution(mL)		50.0	50.0	50.0	50.0
Volume of gas(mL)		106.4	106.4	106.4	106.4
date		1/24	1/27	1/28	1/31
temperature(^{o}C)		21.5	19.9	20.0	19.5
shaken	V1(mV)	42.0	42.6	39.6	38.2
	P1(mmHg)	840.73	841.92	835.96	833.17
	V2(mV)	40.0	40.4	37.3	36.5
	P2(mmHg)	836.75	837.55	831.38	829.79
unshaken	V3(mV)	41.1	47.1()	37.8	41.1
	P3(mmHg)	838.94	850.87	832.38	838.94
	V4(mV)	39.3	46.1	36.2	39.7
	P4(mmHg)	835.36	848.88	829.19	836.15
Dissolution of oxygen(mM)		0.0870	0.0533	0.0309	0.0065

※ Kaohsiung River Middle-course　　　Table5-2

		一	二	三	四
Volume of sample solution(mL)		50.0	50.0	50.0	50.0
Volume of gas(mL)		106.4	106.4	106.4	106.4
date		1/25	1/27	1/30	1/31
temperature(^{o}C)		20.0	19.5	20.8	19.5
shaken	V1(mV)	42.1	30.8	37.3	40.8
	P1(mmHg)	840.93	818.46	831.38	838.34
	V2(mV)	39.8	29.6	36.2	39.2
	P2(mmHg)	836.35	816.07	829.19	835.16
unshaken	V3(mV)	48.0	31.1	39.0	38.8
	P3(mmHg)	852.66	819.05	834.76	834.28
	V4(mV)	46.0	30.1	38.0	37.2
	P4(mmHg)	848.68	817.06	832.77	831.18
Dissolution of oxygen(mM)		0.0145	0.0092	0.0047	0.0015

Kaohsiung River Downstream   Table5-3

		一	二	三	四
Volume of sample solution(mL)		50.0	50.0	50.0	50.0
Volume of gas(mL)		106.4	106.4	106.4	106.4
date		1/25	1/27	1/28	1/31
temperature(^{o}C)		21.5	19.9	21.5	19.5
shaken	V1(mV)	44.5	50.9	47.3	32.0
	P1(mmHg)	845.70	858.43	851.27	820.84
	V2(mV)	42.2	49.3	46.5	30.8
	P2(mmHg)	841.13	855.25	849.68	818.46
unshaken	V3(mV)	51.0	45.2	10.2	43.4
	P3(mmHg)	858.63	847.09	777.49	843.51
	V4(mV)	50.0	44.5	9.9	42.2
	P4(mmHg)	856.64	845.70	776.89	841.13
Dissolution of oxygen(mM)		0.564	0.0384	0.0202	0.0015

※ Kaohsiung River Outlet   Table5-4

		一	二	三	四
Volume of sample solution(mL)		50.0	50.0	50.0	50.0
Volume of gas(mL)		106.4	106.4	106.4	106.4
date		1/26	1/27	1/30	1/31
temperature(^{o}C)		21.0	19.8	21.0	18.0
shaken	V1	12.0	43.1	30.4	36.9
	P1(mmHg)	781.08	842.92	817.67	830.59
	V2	10.7	41.8	29.4	35.7
	P2(mmHg)	778.49	840.33	815.68	828.20
unshaken	V3	10.3	33.0	40.5	39.3()
	P3(mmHg)	777.69	822.83	837.75	835.36
	V4	9.9	32.4	39.8	38.1
	P4(mmHg)	776.89	821.64	836.35	832.97
Dissolution of oxygen(mM)		0.0424	0.0302	0.0123	0.0003
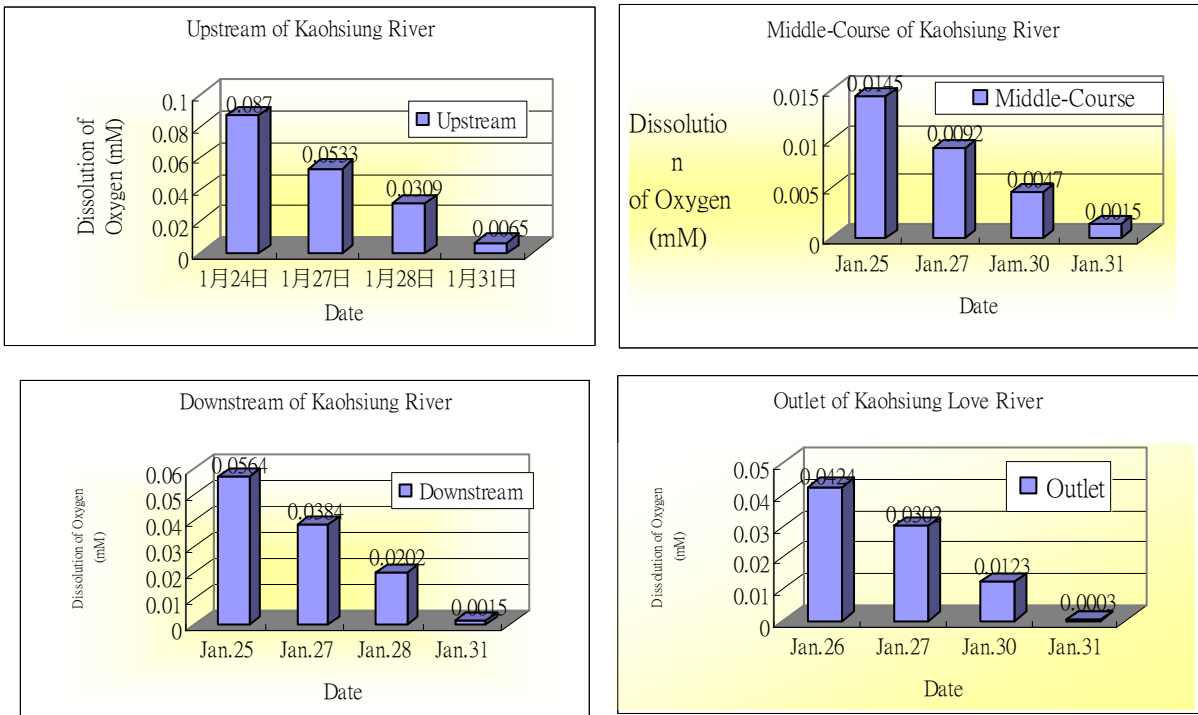
Fig.5-1
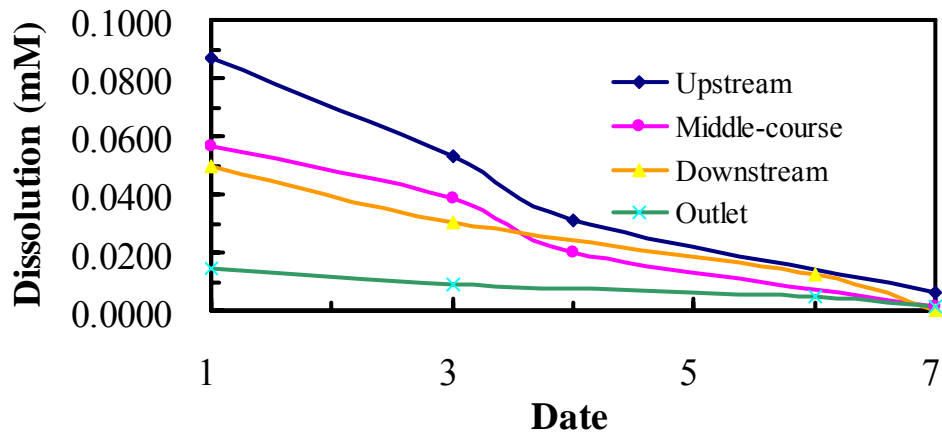
Fig.5-2

B.O.D.

Table5-5

			上游	中游	下游	出海口
Volume of sample solution(mL)			50.0	50.0	50.0	50.0
Volume of gas(mL)			106.4	106.4	106.4	106.4
1st day		temperature(^{o}C)	19.8	19.5	19.9	19.7
	shaken	P1(mmHg)	841.92	840.93	858.43	842.92
		P2(mmHg)	837.5	836.35	855.25	840.33
		m (mM)	0.0967	0.1015	0.0688	0.0571
		P3(mmHg)	850.87	819.05	847.09	822.83
		P4(mmHg)	848.88	817.06	845.70	821.64
		$\triangle$m(mM)	0.0434	0.0587	0.0304	0.0268
		m_0(mM)	0.0533	0.0428	0.0384	0.0303
5st day		temperature (^{o}C)	19.5	19.5	19.5	19.5
	shaken	P1(mmHg)	833.17	838.34	820.84	830.59
		P2(mmHg)	829.79	835.16	818.46	828.20
		m(mM)	0.0755	0.0705	0.0539	0.0535
	unshaken	P3(mmHg)	838.94	834.28	843.51	835.36
		P4(mmHg)	836.15	831.18	841.13	832.97
		$\triangle$m(mM)	0.0690	0.0691	0.0524	0.0532
		m_0(mM)	0.0065	0.0014	0.0015	0.0003
B.O.D. (mM)			0.0468	0.0414	0.0369	0.0300

Upstream   Middle-course   Downstream   Outle

(1) B.O.D. values of each river section are as the right.

     Upstream ＞ Middle-Course ＞ Downstream ＞ Outlet

Table5-6

	Upstream	Middle-Course	Downstream	Outlet
B.O.D. (mM)	0.0468	0.0414	0.0369	0.0300

(2) The correlation of river water's oxygen quantity of each river section is:

Upstream ＞ Middle-Course ＞ Downstream ＞ Outlet, the decreasing progressively trend with time of oxygen quantity under river water is as the above illustration.

IV. Discussion

1. The experiment fastens the vapor pressure gauge to electronic IC PCB by welding tin, and connects the multi-meter and charging battery to assemble the device. Inside the vapor pressure gauge is a subtle film resistor. The pressure differential at both sides of film will cause the deformation of resistor, thus leading to the change in the value of electric resistance. By using electronic IC PCB to connect batteries to form a passage, and also by using multi-meter to read the voltage value at both sides of vapor pressure gauge, the vapor pressure differential can be calculated from both sides of film resistor.
   Improvement1: The electronic IC PCB is sliced into smaller area for the convenience of connecting gauges in every experiment. One of the sides of film resistors is taken to connect with atmosphere. And the other side is connected with pressure system expected to be measured. Because the pressure system expected to be measured is non-vacuum, there is originally atmosphere pressure in the system. Therefore, the pressure differential from both sides is vapor pressure or air pressure expected to be measured.

2. In experiment II, the conical flask serves as a closed space. Near the conical flask, a plastic tube is connected to air pump to change the pressure differential inside and outside the flask. The flask mouth is sealed by cork. And holes are drilled to connect the vapor pressure gauge and mercury pressure gauge.
   Improvement 1: Use airproof tape, hot melt adhesive to seal the plastic tube and vapor pressure gauge. And the calibration curve is accurately fabricated for non-commercial vapor pressure gauge.
   Improvement 2: Coupled with mercury pressure gauge in physical experiment, and by making use of the mercury pressure gauge in physical laboratory, an accurate calibration curve can be made for non-commercial vapor pressure gauge.
   Improvement 3: coupled with mercury pressure gauge in physical experiment, the use of school physical laboratory's mercury pressure gauge can accurately fabricate calibration curve for vapor pressure gauge.

3. In experiment III, connect two syringes of the same volume to both ends of T tube. The third end is connected to vapor pressure gauge. The T tube is uses as vapor chamber for pushing the left syringe while pulling the right syringe. The volume of vapor chamber must remain stable for getting rid off the influence that changing volume has on vapor pressure.
   Improvement : The pointed mouth of syringe is cut off. In experiment, the gauge leans slightly towards the right side (the end for pumping liquid)to pump up the liquid in the tube.

   (1)In 1908, American chemist Gilbert N. Lewis asserts the concept f(Fugacity)in the bibliography as follows:
      a. Ideal vapor and chemical potential has the following relation:
         $\mu = \mu_o + RT \ln P/P_o$. The defined actual vapor and chemical potential have similar relation $\mu = \mu_o + RT \ln f/f_o$ $f = \Phi P$
         Φf. Fugacity's unit is the same as pressure. It replaces the pressure P in Raoul's Law.
      b. Its meaning lies in the fact that in actual conditions, f(Fugacity) replaces the pressure P in ideal conditions. It predicts the transformation of matters accurately(liquid changes to vapor, vapor changes to liquid).So the experiment data result can be slightly corrected to match the real condition. The follow-up research of this experiment will continue to discuss this portion.

4. In experiment IV, a plastic bottle is used as a container for pure liquid expected to be measured. By drilling a hole at the mouth of bottle and connecting to vapor pressure gauge, and also by drilling holes on its side, and connecting to triple valves as a switch, the internal and external pressure differential can be adjusted. The plastic bottle is heated in thermostatic bath to change the value of vapor pressure measured under different temperatures. The iron rack is used to fix the plastic bottle and prevent the water in the thermostatic bath from rocking while circulating.

Improvement 1: A cork is substituted for a bottle lid and connect to vapor pressure gauge closely using AB adhesive and PVC dirt. Add one hole to put in a thermometer and measure the value of temperature for liquid expected to be measured, which substitutes for temperature of thermostatic bath. This is to prevent the inaccuracy cased by the inconsistency in the temperature inside and outside the bottle.

Improvement 2: In every experiment, the liquid expected to be measured is heated to a common initial temperature to calculate the change in pressure caused by heating the vapor in the bottle, and also correct the inaccuracy while reading the vapor pressure value.

Improvement 3: In order to avoid the increase in air pressure in the heat-up procedure that causes inaccuracy, the improvement method is that: dip the container in the water, and only expose the lid. Then heat up the liquid that will be infused to initial temperature. At this time, turn on the switch on the lid to connect the inside and outside. After reaching balance, turn off the triple valves. At this moment, infuse the liquid to increase the volume inside the bottle.(refer to experiment step 1)

5. In experiment V, one hole is drilled in a cork to connect to the three valves, which serve as a switch. Connect it to the steel bottle containing vapor expected to be measured. Infuse the vapor to change the partial pressure of this vapor in the bottle. After adding to pressure to reach a equilibrium, use a syringe to connect to three valves and slowly pump out the vapor. This is to reduce the vapor pressure to prevent it from dropping quickly and dissolved vapor from spilling out from water.

Improvement 1: After several experiments, plastic bottles can be easily deformed due to the drastic change of pressure inside and outside it. Therefore, an acrylic mug is finally chosen to reduce the inaccuracy due to the deformation of bottle.

Improvement 2: Because the vapor that is hard to dissolve has tiny solubility, the traditional multi-meter cannot easily detect the voltage change. So by connecting this gauge to a digital multi-meter, we can measure the change more accurately.

(1) In the experiment operations, oxygen (CO_2) is infused by the method of collection process with displacement of water which makes the proportion of air and infusing gas don't change freely while performing pressure rises and declination. The system total pressure measured at this moment is the partial pressure of the gas.

(2) I Control the pressure of initial oxygen (CO_2), the obtained different initial balance pressures are the different balance status respectively. The effect of pressure towards value k could be measured by different initial pressures in order to explore Henry's Law.

(3) I While performing pressure rise and declination during the experiment procedures, to shake the cone bottle body could increase the touching area of water solution and gas to accelerate the dissolution balance.

6. In experiment VI, the plastic bottle is put in an ultrasonic oscillator until the vapors dissolved in the river water all spill out. Infuse the oxygen to make it saturated, then measure the maximum dissolved oxygen of this river water to be a comparison value for the river water that has not undergone ultrasonic oscillator. The actual amount of dissolved oxygen is extrapolated. The measured additional soluble oxygen quantity in river water of each river section during experiments should be compared after converting into identical standard according to the oxygen partial pressure during measurement. The conversion method is as the right: Measured

oxygen quantity × oxygen partial pressure in air ÷ balance end pressure.

(1) During the experiment operations, oxygen should be infused into in the first place by the method of collection process with displacement of water and rise pressure to initial pressure and then pour into river water which can decrease the touching time of oxygen and river water to decrease the experiment inaccuracy.

(2) Biochemical oxygen demand, BOD for short)

    a. Definition: The total consuming quantity of oxygen for bacteria to decompose waste material in sewage is called biochemical oxygen demand; that is, BOD.

    b. Determination Method:

        ① Let distilled water keep in 20℃, and then fill oxygen to make it achieve saturation and measure the oxygen quantity.

        ② Take a portion of waste water to be measured and place in the distilled water and keep 20℃ to cultivate 5 days (needed to be separated from external oxygen), and then measure the left oxygen quantity within water.

In the experiment operation method of cultivating procedure, the constant temperature and sealing stable system is achieved by thermos mugs. Because of the additional oxygen pressure changes during measurement, part of river water is taken to be measured by the method of sampling.

(3) While measuring oxygen quantity, measure the oxygen pressure variation by shaken and non-shaking river water respectively, and the initial oxygen quantity of original solution could be calculated through the comparison. The river water oxygen quantity is calculated by indirect method. If figure out the oxygen quantity through measuring the pressure variation while river water is shaken directly, because the pressure variation may be from other dissolved gas within river water other than oxygen, the inaccuracy easily occurred; as a res ult, it should be calculated by indirect method.

V. Conclusion

1. A simple pressure gauge was assembled and the calibration curve of difference gases were obtained.
2. The Raoult's Law and the behavior of non-ideal solution mixtures were investigated.
3. The enthalpy of vaporization (ΔH) for different liquid samples were evaluated.
4. The Henry's Law is examined and the proportional constant k for O_2 and CO_2 were determined.
5. The gauge is applied to determine B.O.D value of water from the Kaohsiung River.

VI. References

1.CRC Handbook of Chemistry and Physics, (CRC Press, 1999)

2.Physical Chemistry, by I. Levine (McGraw-Hill, New York, 1987)

3.Physical Chemistry, by Z.T. Tou (Sun-Min, Taipei,1997) (in Chinese)

4.Physical Chemistry by F.T. Tien (Kao-Li, 1999) (in Chinese)

5.CRC handbook of chemistry and physics U.S.A.：CRC Press 1999

6.IRAN、LEVINE，PHYSICAL、CHEMISTRY，McGraw-Hill，Inc，New York，1987

評語

實驗設計簡單且有相當的創意及實用價值。BOD 實驗若能和國家標準方法之測值做更完整及仔細的探討，會更增加作品的水平。