T-07 Henry Law's Constant

Collect:

- Pressure gauge
- Check if the plastic padding is complete and if the gauge is calibrated

Prepare:

- A plastic soda bottle (600-1000 mL)

(2011/12/23 revised)

Introduction

Henry's Law: under constant temperature, the concentration of gas that dissolved in solution is proportional to the partial pressure of gas

$P = K \cdot M$

P: partial pressure of solute (gas) above the solution

M: concentration of solute in the solution

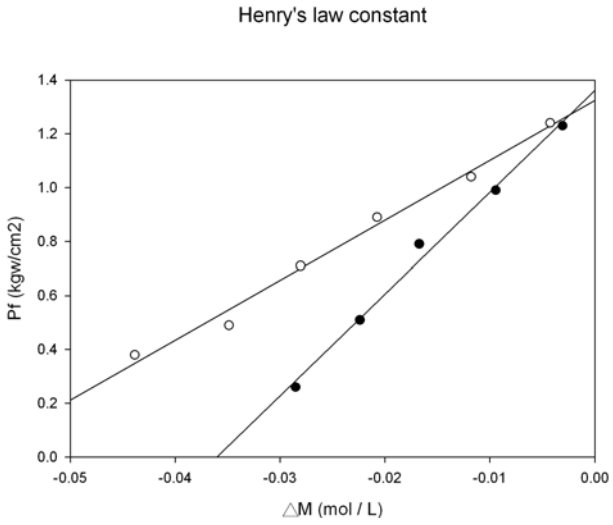
K: Henry's law constant

$$P_i = K \cdot M_i \qquad (1)$$

$$P_f = K \cdot M_f \qquad (2)$$

(2) – (1) $\quad P_f - P_i = K(M_f - M_i) = K \cdot \Delta M$

$$\mathbf{P_f = K \cdot \Delta M + P_i}$$



Slope = K

Procedure 1. Measuring the Volume

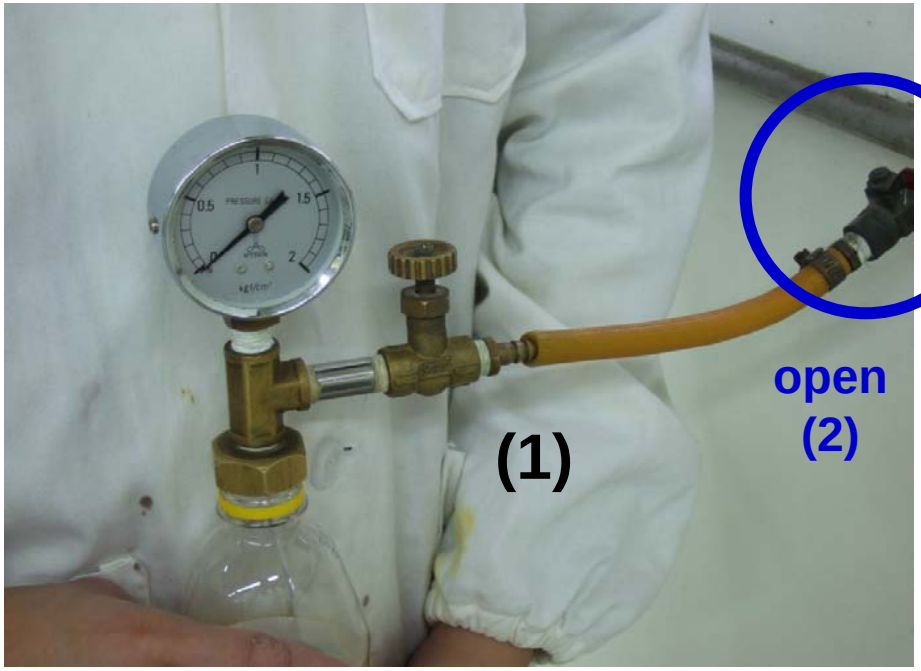
- Measure by weighing or by graduated cylinder
- Plastic soda bottle (600~1000 mL)
- Measure the weight of empty bottle
- Fill with water and measure the weight, then convert into volume
- Pour out 1/3 of water, then measure again
- Calculate volume of water in bottle V_l
- Calculate volume of gas in bottle V_g

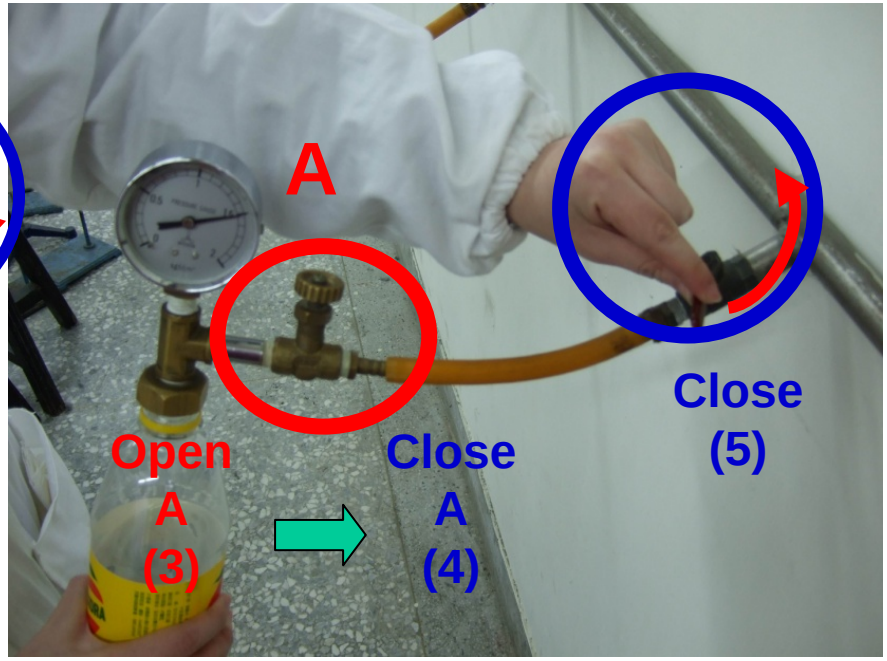
Procedure 2. Set up Pressure Gauge

- Check for any gas leak
- Calibrate pressure gauge
- Close **(A)** gas valve
- Connect pressure gauge to soda bottle, tighten and then turn another 45º
- Squeeze bottle to check for gas leak

Notice: Do not tighten the pressure gauge too tight or tilt the gauge to prevent the opening of the bottle from abrasions

Procedure 3. Fill With Carbon Dioxide

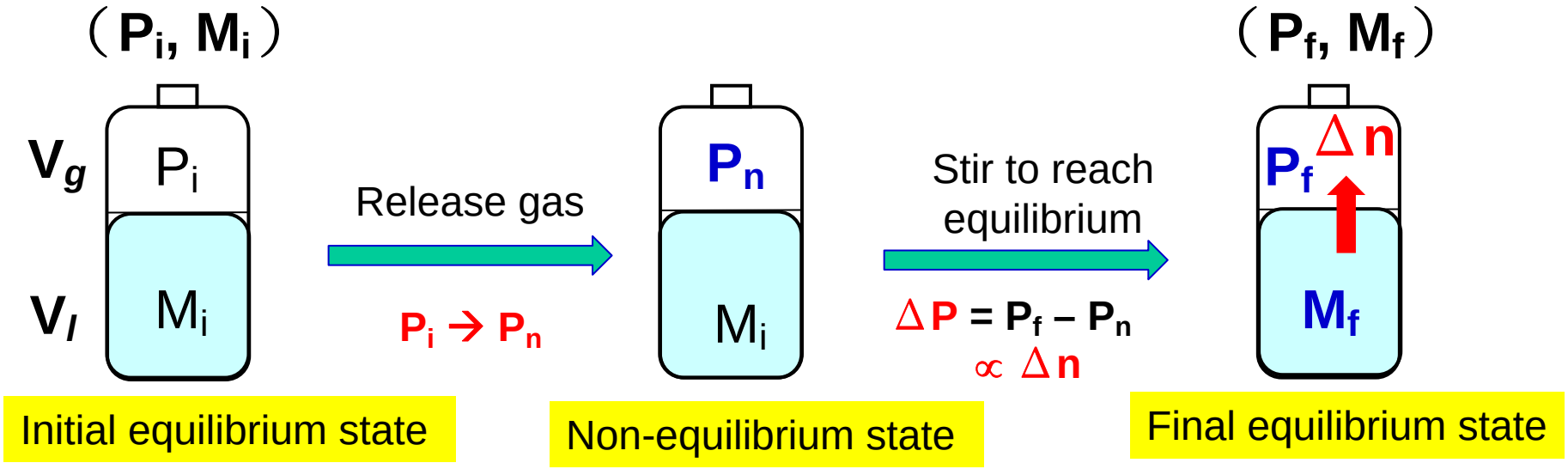




(1) Connect the supplying rubber tube
(2) Open the CO_2–supplying valve about 15°

(3) Open valve A until the pressure gauge reads 1.5 ~ 1.6 kg/cm^2
(4) Close valve A
(5) Close CO_2–supply valve
(6) Swirl bottle to dissolve the CO_2 gas
(7) Repeat CO_2 supply-dissolve steps several times till equilibrium pressure is ca. 1.5 kg/cm^2

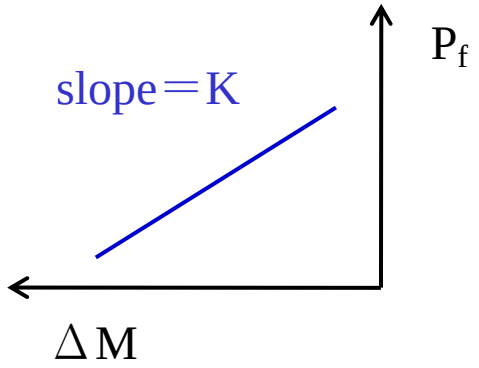
Outline of Procedures



- **Number of moles of CO_2 increased in gaseous state**
  = Number of moles of CO_2 decreased in liquid

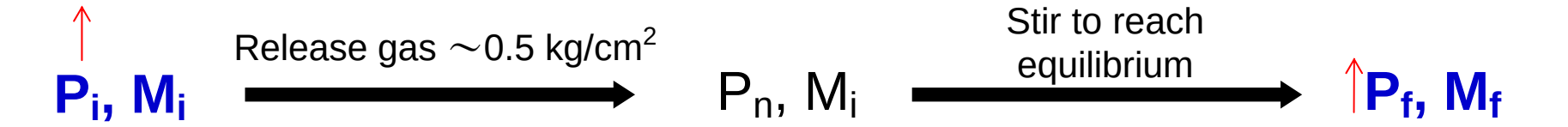
$$\Delta n = \frac{\Delta P V_g}{RT} \quad \Rightarrow \quad \Delta m = \frac{-\Delta P V_g}{RT V_l}$$

- $P_f = K \cdot \Delta M + P_i$



Procedure (I): Henry's Law Constant When Air Is inside Bottle ($P_{air} + P_{CO_2}$)

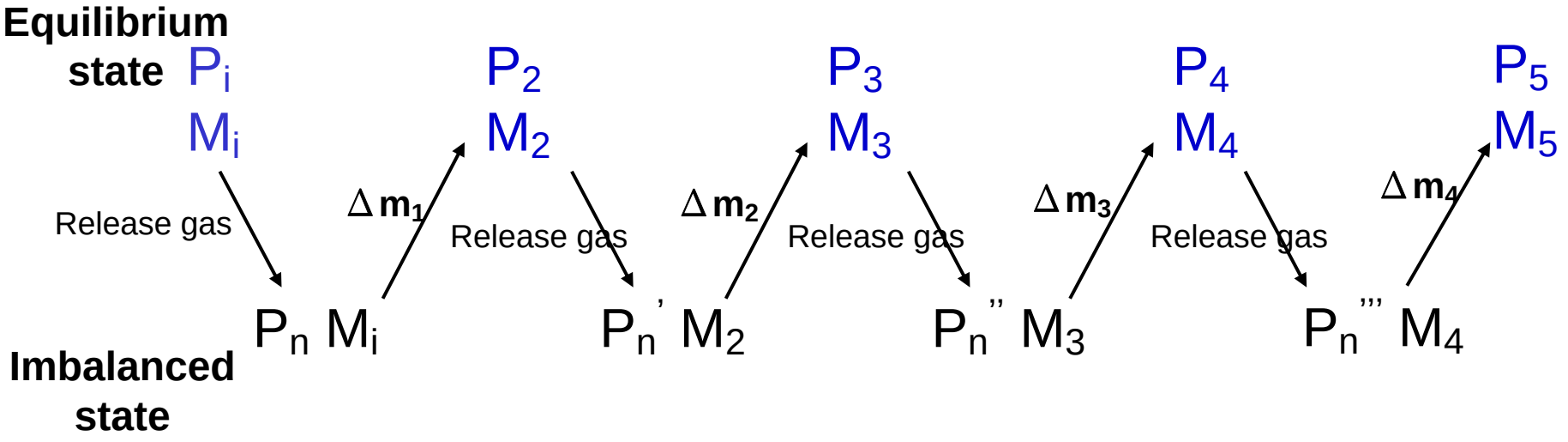
P_{CO_2} = 1.5~1.6 kg/cm^2



Initial equilibrium state

Non-equilibrium state

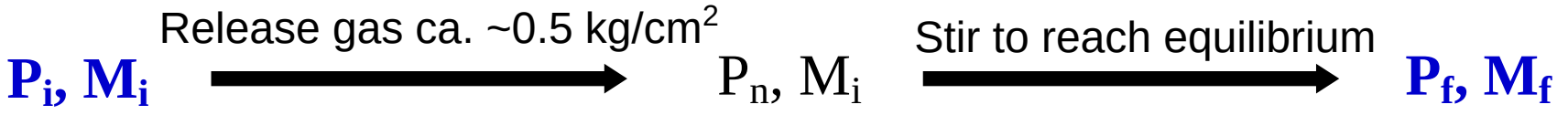
Final equilibrium state



Procedure (II): Henry Law's Constant without Air ($P = P_{CO_2}$)

- Continue using the above soda bottle, do not remove pressure gauge
- Adding and releasing the bottle with CO_2 gas three times until all air is flushed out of the bottle
- **Repeat steps in procedure (I)**

P_{CO_2} = 1.5~1.6 kg/cm^2



Initial equilibrium state | Non-equilibrium state | Final equilibrium state

Data Analysis

P_i	P_n (kg/cm^2)	P_f (kg/cm^2)	**ΔP** (kg/cm^2)	ΔP (atm)	**Δm** (mol/L)	ΔM (mol/L)
1.52	1.00	1.30	0.30	0.29	-0.0045	-0.0045
	0.81	1.10	0.29	0.28	-0.0044	-0.0089
	0.61	0.90	0.29	0.28	-0.0044	-0.0133
	0.41	0.72	0.31	0.30	-0.0047	-0.0180

P_i	P_n (kg/cm^2)	P_f (kg/cm^2)	ΔP (kg/cm^2)	ΔP (atm)	Δm (mol/L)	ΔM (mol/L)
1.59	1.09	1.30	0.21	0.20	-0.0032	-0.0032
	0.81	1.18	0.37	0.36	-0.0056	-0.0088
	0.71	1.08	0.37	0.36	-0.0056	-0.0144
	0.60	0.95	0.35	0.34	-0.0053	-0.0196

Data Analysis

- ΔP **(= $P_f - P_n$)** $\rightarrow \Delta n \rightarrow \Delta m \rightarrow \Delta M$

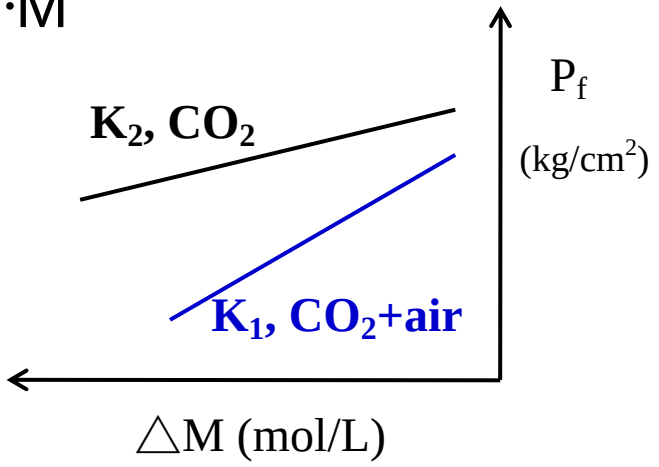
  (1) Unit for pressure gauge: kg/cm^2, need to convert to atm when calculating Δn

  (2) Δm should be negative ($[CO_2]$ in water decreases)

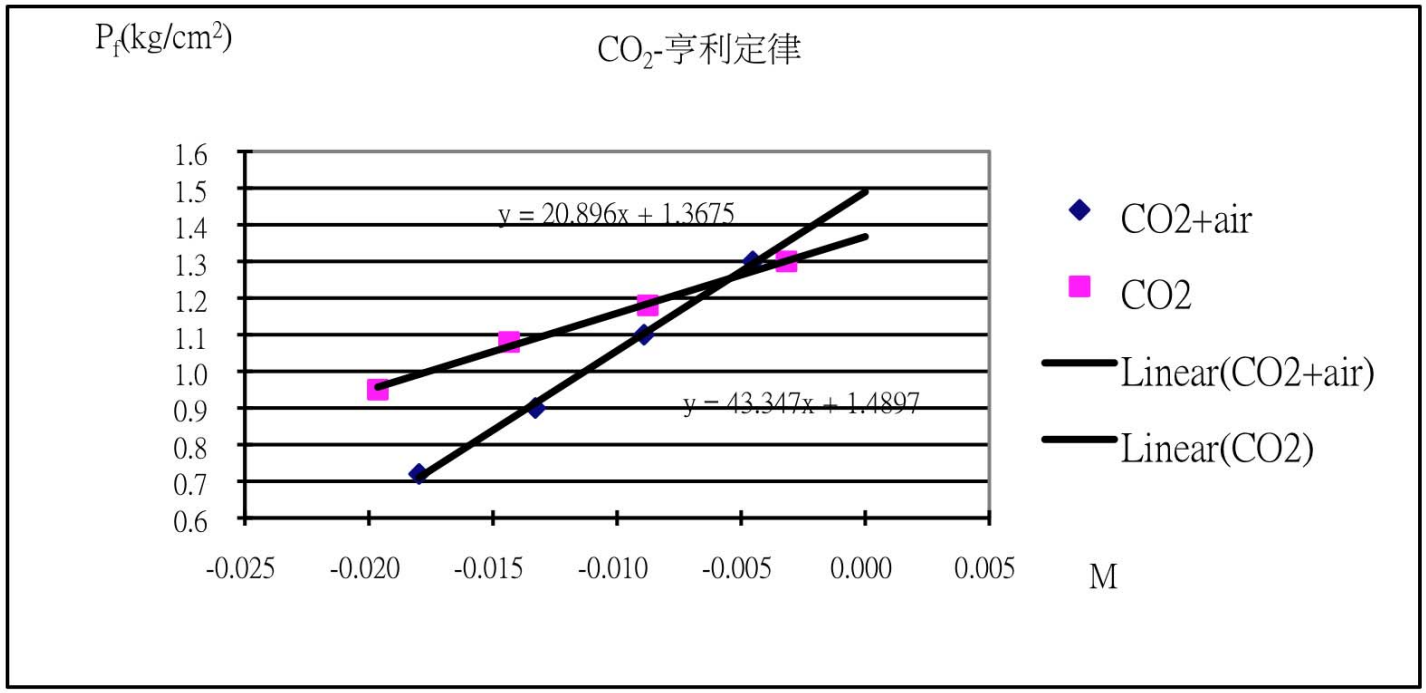
- Graph should include 2 regression lines to obtain 2 slopes for Henry law's constant K_1 and K_2
- K with positive value and unit: $kg/cm^2 \cdot M$

K_1: Approx. 1 atm of air inside bottle originally

K_2: Approx. 1 atm of CO_2 inside bottle originally, which means the bottle is completely filled with CO_2, approaching theoretical value



Graph Obtained by Experiment



For example:

K_1 (Air+CO_2) = 43 kg/cm^2·M

K_2 (CO_2) = 20 kg/cm^2·M

Notice

- Calibrate pressure gauge and avoid gas leak
- Use 600-1000 mL plastic soda bottle
- Do not use mineral water bottle (cannot withstand pressure)
- If there is a gas leak, use soap water and apply to connecting areas to check for gas leak (ask for help from TA)
- The unit on the pressure gauge is kgf/cm^2 equal to kg/cm^2
- Record the room temperature of the day, Henry law's constant changes with temperature
- Recycle the soda bottle