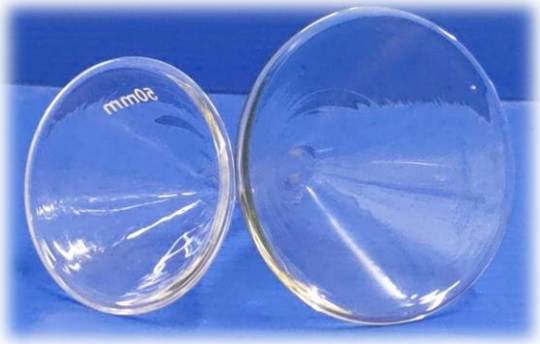
Solubility Product Constant of Silver Acetate

Last revised: 2024/03/31

Preparation

Collect the following items

- One magnetic stir bar (TA will distribute)
- One 25 mL buret, four 125 mL Erlenmeyer flasks
- One 10 mL graduated pipet and one pipet filler
- **Three** glass funnels and one 100 mL beaker
- Ring clamp, Styrofoam cup, NBR gloves



From your personal equipment

- **Four** 100 mL beakers

Preparation

- Take two clean and dry 100 mL beakers to prepare saturated AgOAc solution
- Wash clean and oven dry two glass funnels (φ 70) and three 100 mL beakers (label group no. on beaker)

Notes

The concentrations of chemicals are changed, which affects the calculation of K_{sp}

Chemicals (p.134)

- 0.020 M Potassium thiocyanate, KSCN
- 0.10 M Silver acetate, $AgNO_3$

I. Experimental data (p.137)

- 0.020 M KSCN

Objective and Principles

- **Objective:** Determine the solubility product constant (K_{sp}) of silver acetate (AgOAc) at specific temperatures

- **Lab techniques:**
  - **Gravity filtration**
  - **Using a graduated pipet**
  - **Performing titration using a buret**
  - Hot plate/magnetic stirrer
  - Lab dispenser

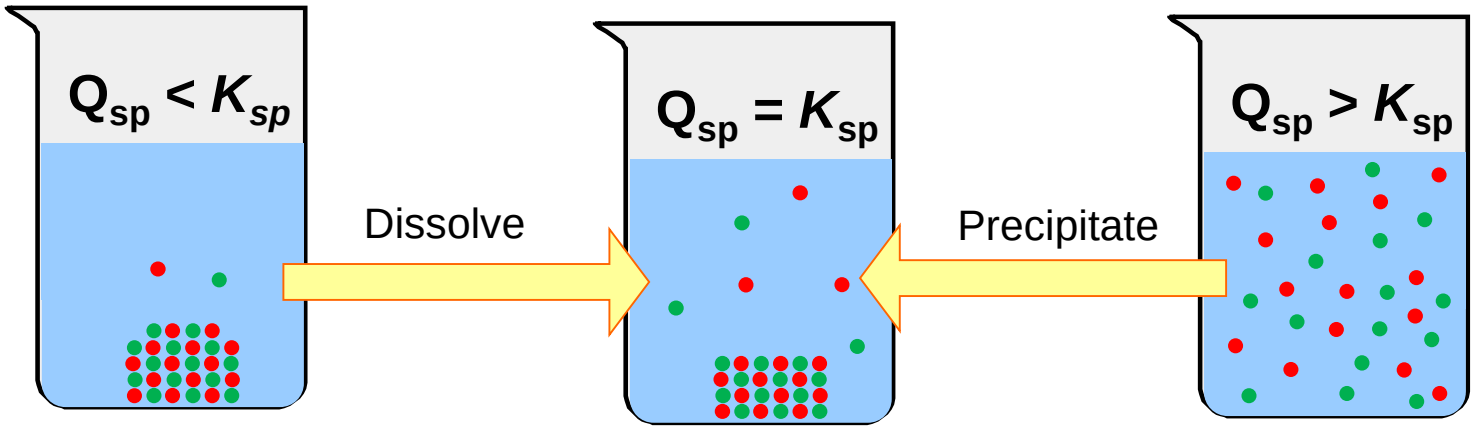
Solubility Product Constant

- K_{sp} is a specific type of equilibrium constant that describes the dissolution process of salts in water:

$$A_mB_n(s) \rightleftharpoons mA^{n+}(aq) + nB^{m-}(aq)$$

$$K_{sp} = [A^{n+}]^m[B^{m-}]^n$$

- When the ion product (Q) exceeds K_{sp}, precipitates would form until the Q value in the solution equals to K_{sp}



Solubility Product Constant

- For any specific salt, its K_{sp} changes with temperature but stays independent of pH and the concentrations of ions in the solution
- Nevertheless, the *solubility* of salts may be affected by the presence of other ions (common ion effect)

Solubility of AgCl in pure water

$$AgCl(s) \rightleftharpoons Ag^+(aq) + Cl^-(aq)$$

$$K_{sp} = [Ag^+][Cl^-] = 1.6 \times 10^{-10}$$

Initial		0	0
Change	− x	+ x	+ x
equi.		x	x

$x^2 = 1.6 \times 10^{-10}$

→ $x = 1.3 \times 10^{-5}$ (M)

Solubility of AgCl in 0.01 M NaCl

$$AgCl(s) \rightleftharpoons Ag^+(aq) + Cl^-(aq)$$

$$K_{sp} = [Ag^+][Cl^-] = 1.6 \times 10^{-10}$$

Initial		0	**0.01**
Change	− x	+ x	+ x
equi.		x	**0.01** + x

$x(0.01 + x)$

$\simeq (0.01)\, x = 1.6 \times 10^{-10}$

→ $x = 1.6 \times 10^{-8}$ (M)

Experiment Tasks

1. Prepare saturated silver acetate solution
2. Remove excess AgOAc precipitate
3. Use a standard SCN^- solution to titrate and determine $[Ag^+]$
4. Based on the known $[OAc^-]$, calculate $K_{sp}(AgOAc) = [Ag^+][OAc^-]$
5. Perform the same procedures in both room temperature and a lower temperature

$AgNO_3(aq) + NaOAc(aq) \rightarrow AgOAc(s) + NaNO_3(aq)$ Precipitation

$AgOAc(s) \rightleftharpoons Ag^+(aq) + OAc^-(aq)$ Solubility equilibrium

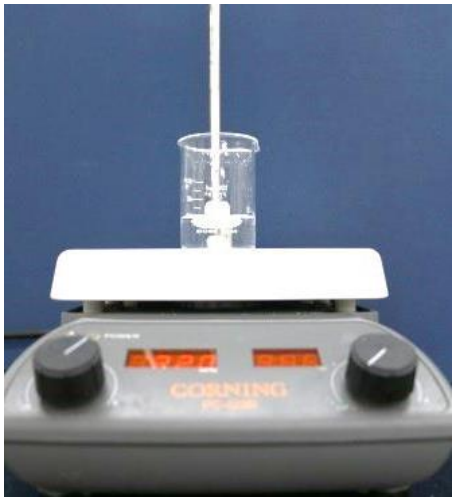
$Ag^+(aq) + SCN^-(aq) \rightarrow AgSCN(s)$ Precipitation titration

$Fe^{3+}(aq) + SCN^-(aq) \rightleftharpoons \mathbf{\mathit{FeSCN^{2+}(aq)}}$ Red complex indicates the titration end point

Step 1: Prepare Saturated AgOAc Solution

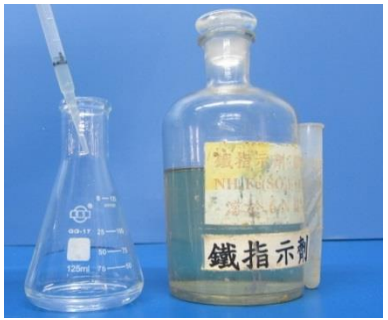
- Use a clean and dry 100 mL beaker to take 10.0 mL **0.10 M of $AgNO_3$(aq)** and 15.0 mL of 0.30 M NaOAc(aq)

- Add the magnetic stirrer into the beaker, stir for **15** minutes
- Record the solution temperature

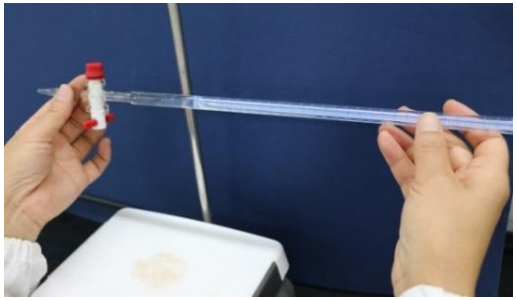


Step 2: Filtration to Remove AgOAc Ppt

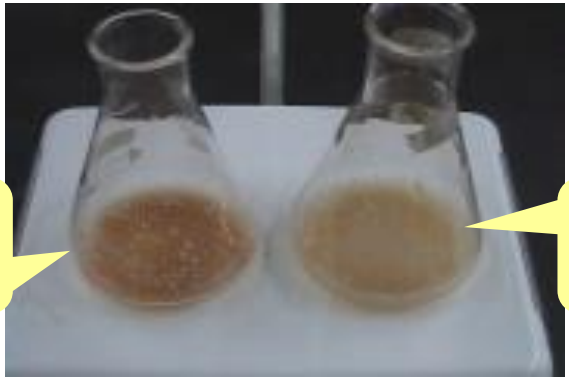
- Take a 110-mm diameter filter paper, fold it twice and tear off a small piece at one of the two thin outside corners
- Use a ring clamp to set up a glass funnel; expand the filter paper and install it in the funnel
- Perform gravity filtration to remove AgOAc precipitate and collect the filtrate in a 100 mL beaker
- Rinse a graduate pipet with few AgOAc(aq) filtrate then transfer assigned portion into 125 mL Erlenmeyer flasks
  - **5.00 mL** (coarse titration)
  - **10.00 mL** (fine titration)
- Add **1 mL of Fe^{3+} indicator**



Step 3: Titration of [Ag^+]

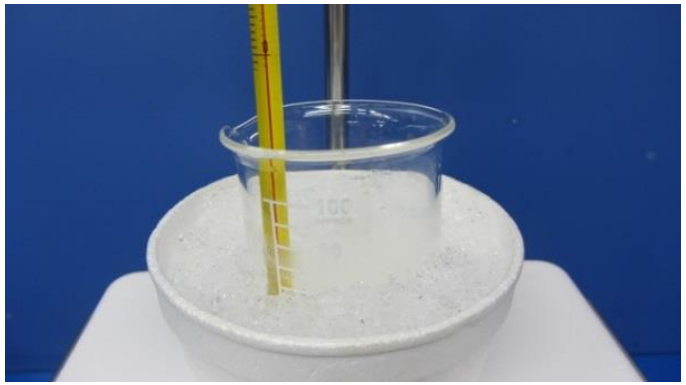


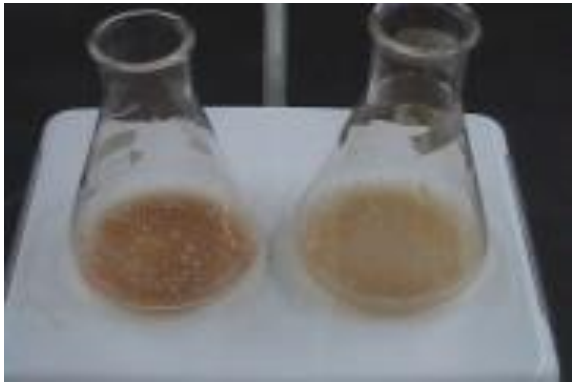
- Use a clean and dry 100 mL beaker to take **40.0 mL 0.020 M KSCN(aq)**
- Rinse the buret twice with KSCN solution, then fill the buret
- Titrate the AgOAc solution with **0.020 M KSCN** until the solution appears a light orange color (read and record V_i and V_f to 0.01 mL)



Step 4: K_{sp} at Low Temperature

- Use another clean and dry 100 mL beaker and take 10.0 mL **0.10 M of $AgNO_3$(aq)** and 15.0 mL of 0.30 M NaOAc(aq)
- Stir and mix the solution in an ice-water bath for **15** minutes, record the temperature of solution
- Repeat Steps 2 & 3 to determine [Ag^+] in saturated AgOAc(aq)





Calculate [OAc⁻]

$$Ag^+(aq) + OAc^-(aq) \rightarrow AgOAc(s)$$

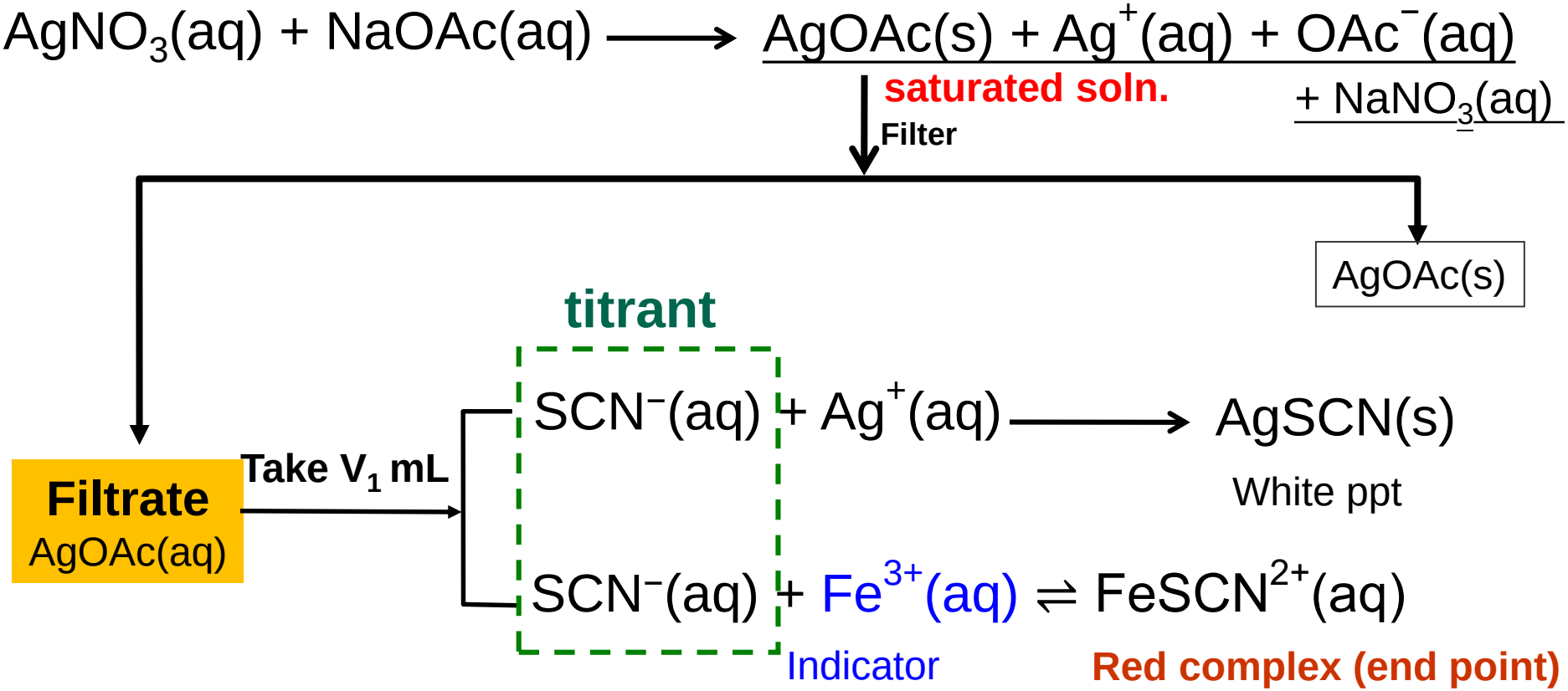
Before mixing 10.0 mL × 0.10 M = 1.0 mmol 15.0 mL × 0.30 M = 4.5 mmol (excess)

After mixing 1.0 – 1.0 = 0 mmol 4.5 – 1.0 = 3.5 mmol 1.0 mmol
Ppt. occurs

- Because the K_{sp} of AgOAc is quite small, the precipitation reaction is assumed to be completed with NaOAc being the excess reagent
- Total volume after mixing = 25.0 mL

Excess reagent: $[OAc^-] = \frac{3.5\ mmol}{25.0\ mL} = 0.14\ M$

Calculate [Ag^+] (Volhard Method)



- SCN^- reacts with Ag^+ first
- At titration end point, # moles Ag^+ = # moles SCN^-
- **$[Ag^+] \times V_1 = [SCN^-] \times (V_f - V_i)$**

Calculate K_{sp} of AgOAc

$$AgOAc(s) \rightleftharpoons Ag^{+}(aq) + OAc^{-}(aq)$$

Concentration before Equilibrium	**0 M**	**0.14 M**
Concentration after Dissolution equilibrium	**x M**	**(0.14 + x) M**

$$K_{sp} = [Ag^{+}][OAc^{-}] = x\,(0.14 + x)$$

Additional Notes

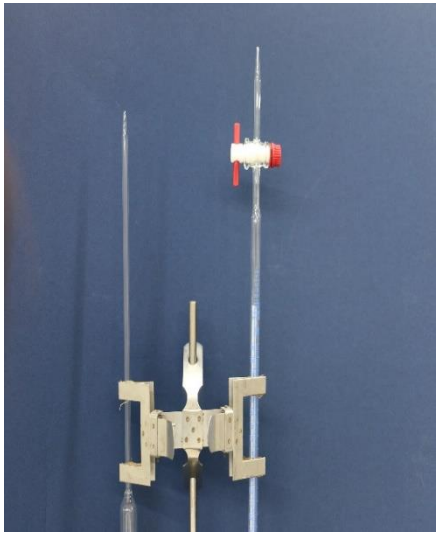
- Use only clean and dry beakers for mixing $AgNO_3$ and NaOAc
- Rinse the graduated pipet with sat. AgOAc(aq), and rinse the buret with KSCN(aq) to ensure that $[Ag^+]$ can be accurately determined
- Take only **40 mL 0.020 M KSCN(aq)** by lab dispenser
- Add **1 mL Fe^{3+}** indicator for each titration (not 1 drop)
- Temperature of AgOAc(aq) should be recorded right before the gravity filtration step
- Avoid contacting $AgNO_3$(aq) or AgOAc(aq) with skin (wear NBR gloves at all times)
- Be careful in not losing the magnetic stir bar into the sink or waste bin

Clean-Up and Check-Out

Brief Report

- Ag-containing solution and precipitates should be disposed into the designated heavy metal waste bin
- The cleaned buret and transfer pipet should be clamped upside-down on the buret clamp
- Wash Erlenmeyer flasks thoroughly with brush and detergent
- Return the magnetic stir bar to TA
- Clean up the lab bench and check personal equipment inventory (have an associate TA sign the check list)
- This is a **Brief Report** experiment:

- Groups on duty shall stay and help clean up the lab



Example of Experimental Data

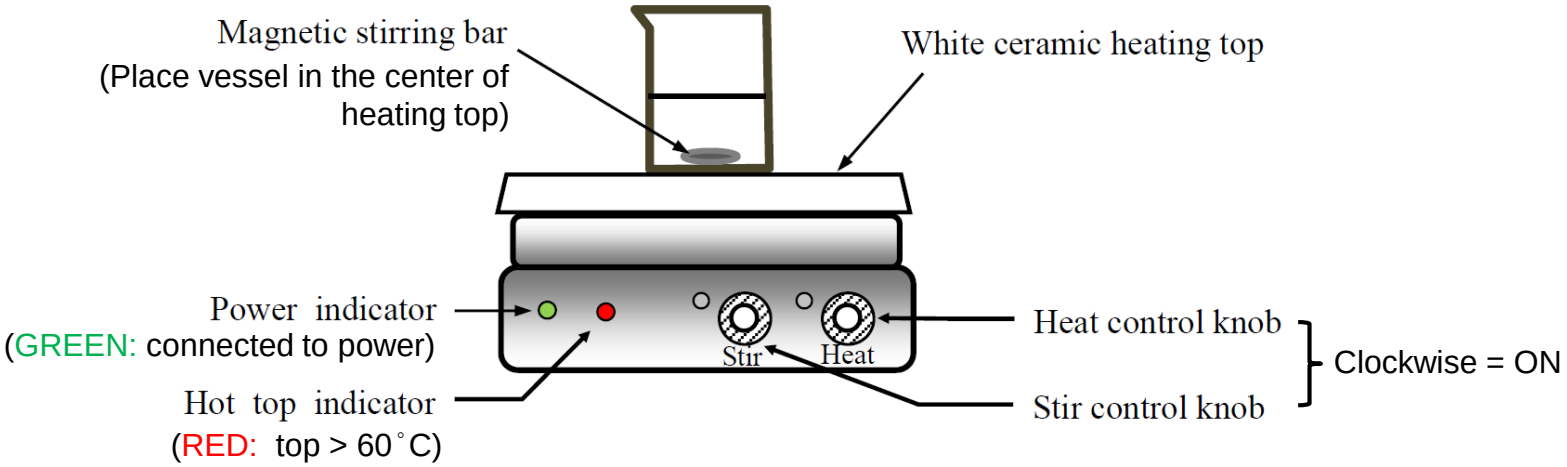
Test item		Room temp. (°C) (ex. 24.0 °C)		Ice bath (°C) (ex. 3.5 °C)	
		Coarse titration	Fine titration	Coarse titration	Fine titration
Volume of saturated AgOAc (mL)		5.00	10.00	5.00	10.00
0.020 M KSCN	V_i (mL)				
	V_f (mL)				
Titration volume	ΔV (mL)				

Calculate $[Ag^+]$, $[OAc^-]$, and K_{sp}

Temp. (°C)	(1) 24.0	(2) 3.5
$[Ag^+]$ (M)	$[Ag^+] \times 10.00 = 0.020 \times 11.11$ $[Ag^+] = 0.023$	
$[OAc^-]$ (M)	$0.14 + 0.023 = 0.16$	
K_{sp}	3.7×10^{-3}	

*** Compare the K_{sp} of silver acetate at different temperature**

T2 – Stirrer/Hot Plate



- Connect the stirre/hot plate to a grounded 110 V power outlet (replace damaged power cord and plug immediately)
- Keep power cord away from the ceramic heating top
- Clean the heating top with non-corrosive detergent after use or when liquid spills
- NEVER heat a large amount of volatile and flammable liquid (e.g. ether, acetone) directly on the hot plate
- If the stirring bar jumps erratically, turn the stirring function off and adjust the vessel position, then restart the stirring
- Do not remove the stirring bar from solution with hand – instead use a Teflon-coated magnetic rod (“fishing pole”)

T2 Video (YouTube link)

T6 – Gravity Filtration

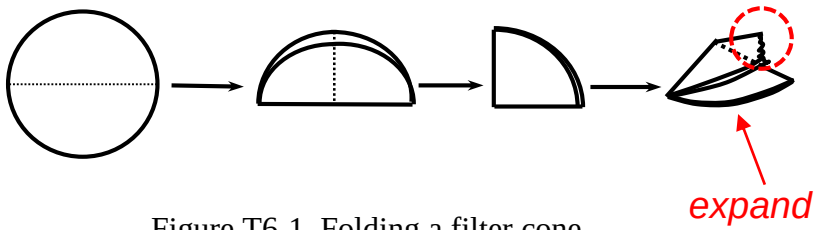


Figure T6-1 Folding a filter cone

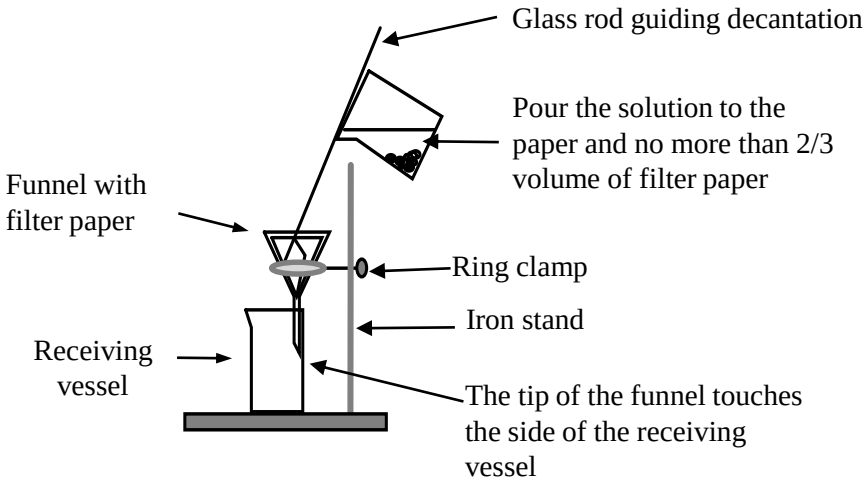


Figure T6-2 Setup of gravity filtration

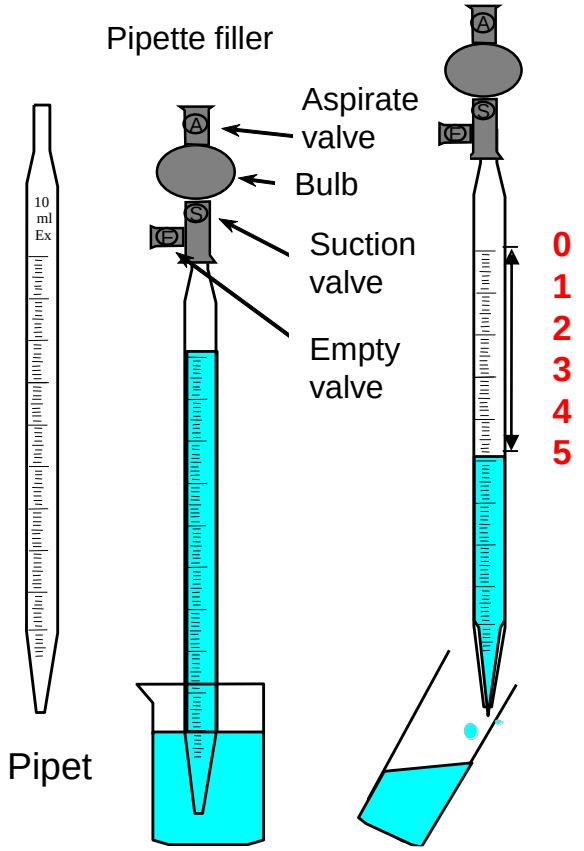
- Fold a round filter paper in half for two times. Tear off a small piece at one of the two thin outside corners
- Expand the filter paper (from the intact fold) into a cone shape. Fit the filter paper into a funnel (the edge of filter paper should not exceed the top of funnel)
- Use a ring clamp to support the glass funnel. The tip of the funnel should touch the sidewall of the receiving vessel
- Pour the liquid into the paper cone (not on the glass funnel). Use a glass rod to decant the liquid
- Fill the paper cone no more than 2/3 full
- After filtration, use a tweezer to separate the filter paper from funnel (don't use hand)

T6 Video (YouTube link)

T12.2 – Measuring (Graduated) Pipet

Deliver 5.00 mL solution – Method 1

- Clean a 10 mL pipet and rinse it twice with small amount of the liquid to be transferred
- Press valve **A** of the pipet filler and simultaneously squeeze the bulb to expel air from it, then insert the top of pipet gently into the pipet filler
- Bring the pipet tip below the liquid surface, press valve **S** to draw liquid to the 0.00 mL marking
- Wipe off any excess liquid near the pipet tip
- Use the other hand to hold the new container. Maintain the pipet in a vertical position and let its tip touch the inner wall of the container. Press valve **E** to drain the liquid to the 5.00 mL marking
- Do not force out any liquid remaining at the tip
- Wash the pipet thoroughly after use

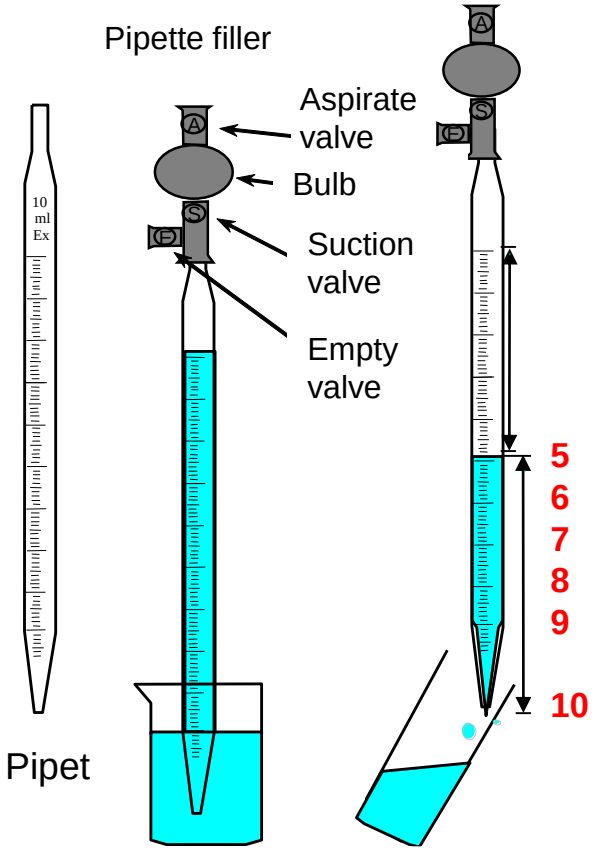


T12 Video (YouTube link)

T12.3 – Measuring (Graduated) Pipet

Deliver 5.00 mL solution – Method 2

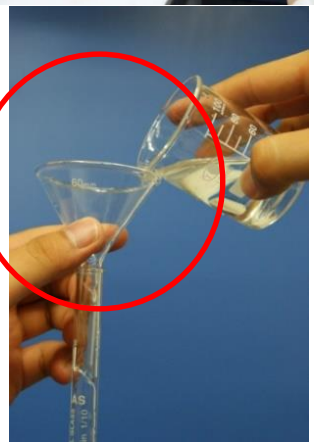
- Clean a 10 mL pipet and rinse it twice with small amount of the liquid to be transferred
- Press valve **A** of the pipet filler and simultaneously squeeze the bulb to expel air from it, then insert the top of pipet gently into the pipet filler
- Bring the pipet tip below the liquid surface, press valve **S** to draw liquid until it rises above the 5.00 mL marking
- Remove the pipet filler and quicky use an index finger to close the top of pipet. Use the finger to adjust the liquid level to the 5.00 mL marking
- Wipe off any excess liquid near the pipet tip
- Use the other hand to hold the new container. Maintain the pipet in a vertical position and let its tip touch the inner wall of the container. Release the index finger so that liquid is transferred
- Do not force out any liquid remaining at the tip
- Wash the pipet thoroughly after use

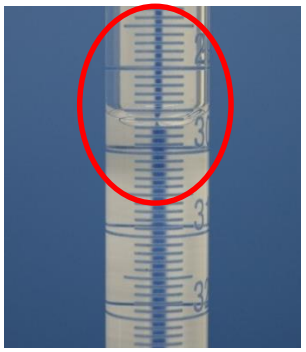


T12 Video (YouTube link)

T14 – Titration

- Clean the buret with DI water, then rinse twice with ~5 mL of titrant (use a funnel to add titrant)
- Open the stopcock to repel the air at the buret tip
- Adjust the height of buret so that its tip is lower than the lid of receiving flask
- Read and record the initial volume (V_i) on the buret to 0.01 mL
- With the stopcock on the right side, use your left hand to control the stopcock while the right hand swirls the receiving flask in a circular motion
- At the titration end point, read and record the final volume (V_f) on the buret to 0.01 mL
- After the experiment, wash the buret and let it dry upside-down on the buret clamp





T14 Video (YouTube link)

Lab Dispenser

1) Check the pre-set volume on the dispenser. Do not change the setting unless instructed to do so
2) Place the receiving flask under the tip of dispenser
3) To remove the air bubbles in the dispenser, lightly pull the piston pump up and down for several times
4) Gently pull the piston pump up until it reaches the end of travel range, then slowly push the piston down to obtain the solution