(a) Plan and Design of the Experiment

Aim:

To determine the concentration and hence the number of moles of water of crystallization, x, in hydrated oxalic acid, $H_2C_2O_4 \cdot xH_2O$, by titrating it against a standard alkaline solution.

Hypothesis:

The hydrated oxalic acid has a concentration of 0.05M and it contains the 2 of water molecules of crystallization.

Variables:

Dependent Variable includes;

Volume of oxalic acid solution (FA2) added during titration.

Independent Variable includes;

Volume of alkaline solution neutralized / titre value obtained.

Controlled Variables include;

- Volume of alkaline solution used

Apparatus:

- Burette
- Pipette (25.0 cm^3)
- Pipette filler
- Conical flask
- Funnel
- Beaker
- Retort stand and clamp
- White tile
- Wash bottle containing distilled water

Chemicals:

- FA1: 0.1M alkaline solution, MOH
- FA2: Oxalic acid solution
- Phenolphthalein indicator
- Distilled water

Choice of Indicator:

Phenolphthalein is the most suitable indicator because:

- Oxalic acid is a weak acid.
- MOH is a strong alkali.
- Phenolphthalein gives a sharp colour change from pink to colourless at the end point.

Risks and Mitigation:

Risk	**Mitigation**
Oxalic acid may irritate skin and eyes	Wear gloves and safety goggles
Alkali solution is corrosive	Avoid contact with skin
Glass apparatus may break	Handle apparatus carefully
Acid spills	Clean immediately with plenty of water

Procedure:

1. Rinse the burette with FA2 (oxalic acid solution) and fill it.
2. Record the initial burette reading.
3. Rinse the pipette with FA1 and use it to transfer 25.0 cm^3 of FA1 into a conical flask.
4. Add 2–3 drops of phenolphthalein indicator.
5. The solution appears pink.
6. Titrate with FA2 while swirling continuously until the pink colour just disappears.
7. Record the final burette reading.
8. Repeat the titration until consistent results are obtained.

(b) Carrying Out the Experiment and Recording Results.

Volume of pipette used = 25.0 cm^3

Titration Results:

Titration	Initial Reading (cm^3)	Final Reading (cm^3)	Volume of FA2 Used (cm^3)
Rough	0.00	24.80	24.80
1	0.00	25.00	25.00
2	25.00	49.90	24.90
3	0.00	24.95	24.95

Average Volume of FA2 Used;

Average titre $= \frac{25.00+24.90+24.95}{3} \quad = 24.95\ \text{cm}^3$

(c) Data Analysis, Conclusion and Recommendation.

Step 1: Equation for the Reaction: $H_2C_2O_4(aq) + 2MOH(aq) \rightarrow M_2C_2O_4(aq) + 2H_2O(l)$

From the equation: 1 mole of oxalic acid reacts with 2 moles of MOH

Step 2: Calculate Moles of MOH Used:

Concentration of MOH = 0.1M

Volume used = 25.0 cm^3

Moles $= \frac{CV}{1000} \quad n = \frac{CV}{1000} \quad = \frac{0.1\times25.0}{1000} \quad = 0.0025$ moles

Step 3: Calculate Moles of Oxalic Acid:

From the mole ratio: Moles of oxalic acid $= \frac{0.0025}{2} \quad = 0.00125$ moles

Step 4: Calculate Concentration of FA2:

Volume of FA2 used = 24.95 cm^3

$C = \frac{1000n}{V} \quad = \frac{1000\times0.00125}{24.95} \quad = 0.0501\ \text{mol dm}^{-3}$

Step 5: Determine Molar Mass of Hydrated Oxalic Acid:

0.63 g dissolved in 100 cm^3 of solution

Therefore, mass in 1 dm^3: $= 0.63 \times 10 = 6.3\ \text{g dm}^{-3}$

Molar mass:

Molar mass $= \frac{\text{mass per dm}^3}{\text{concentration}} \quad = \frac{6.3}{0.0501} \quad \approx 126\ \text{g mol}^{-1}$

Step 6: Determine the Value of x:

Formula: $H_2C_2O_4 \cdot xH_2O$

Molar mass of anhydrous oxalic acid: $(2 \times 1) + (2 \times 12) + (4 \times 16) \quad = 90$

Water contribution: $126 - 90 = 36$

Since one mole of water has mass 18: $x = \frac{36}{18} \quad x = 2$

Conclusion:

The hydrated oxalic acid has the formula: $H_2C_2O_4 \cdot 2H_2O$

Therefore, the value of: $x = 2$

The oxalic acid supplied to the plumber is oxalic acid dihydrate.

Recommendations:

1. The plumber should always use correctly standardized oxalic acid solutions to avoid damaging metal pipes and fittings.
2. Oxalic acid crystals should be stored in tightly closed containers to prevent changes in water of crystallization.
3. Accurate measurements and proper titration techniques should always be followed when preparing cleaning solutions.
4. Protective gloves and goggles should be worn while handling oxalic acid because it is corrosive.