FOLLOW-UP

1 The following equilibrium exists in a buffer solution:

$CH_3COOH(aq) + H_2O(l) \rightleftharpoons CH_3COO^-(aq) + H_3O^+(aq)$

a If more water is added to the above equilibrium, a slight shift to the right is observed according to Le Chatelier's Principle (slightly more acidic). However, this shift is not significant and the pH will not change significantly.

b When extra hydrogen ions are added in the form of acid, ethanoate ions combine with extra H^+ ions and the equilibrium shifts to the left—more ethanoic acid is formed and the pH will stay the same.

c When a base is added, hydronium ions neutralise the OH^- ions and the equilibrium shifts to the right—pH will stay the same.

2 Buffers establish equilibrium in such a way that each side of the equation has an acid and a base present. In the respiratory system, the following equilibrium is established:

$CO_2(g) + H_2O(l) \rightleftharpoons H_2CO_3(aq)$

$H_2CO_3(aq) + H_2O(l) \rightleftharpoons HCO_3^-(aq) + H_3O^+(aq)$

If we inhale acidic gases, they react with water to produce extra hydrogen ions and the equilibrium shifts to the left, as hydrogen carbonate ions combine with extra hydrogen ions. Should we inhale any substance that produces OH^- ions in water, the base shifts the equilibrium to the right as extra hydroxide ions combine with hydronium ions, and more hydrogen carbonate ions are formed.

Sample risk assessment record

INVESTIGATION 30: Hydrolysis of salts

Assessment team: ______________________ Date: ______________________ Year/group: *12*

Ref: *Heinemann Chemistry Practical Manual*

Chemicals used	Conc. (mol/L)	Amount	User code	DG class/ haz	Procedure as per Appendix D?	What are the hazards?
potassium nitrate	0.1	10 mL	7-12	5.1/ CW	yes	Toxic fumes released on heating, moderately toxic if ingested
sodium carbonate	0.1	10 mL	7-12	DHS	yes	Skin irritant, slightly toxic if ingested
ammonium chloride	0.1	10 mL	7-12	DHS	yes	Toxic fumes released on heating, slightly toxic if ingested
sodium acetate	0.1	10 mL	7-12	DHS	yes	Skin irritant, do not mix with potassium nitrate

Disposal of waste

Leftover solutions can be washed down the sink, provided the pH is above 7.

How are risks controlled?

- wear safety glasses
- use gloves
- wash hands after use

Assessment of risk:

Risk for this investigation is **not significant**, provided appropriate control measures are in place as indicated above.

Approved by: ______________________ Date: ______________________

Investigation 31

Preparing standard solutions

Rationale

Students standardise a 0.1 M sodium hydroxide solution with solid potassium hydrogen phthalate, and then use this solution to standardise a 0.1 M HCl solution. Both solutions may be used for Investigation 32.

Syllabus

Perform a first-hand investigation and solve problems using titrations and including the preparation of standard solutions, and use available evidence to quantitatively and qualitatively describe the reaction between selected acids and bases.

Background knowledge

Show students how to titrate and explain the difference between end point and equivalence point. Students have learned already how to prepare solutions to specific volume-to-volume and mass-to-volume specifications, how to dilute them to specified concentrations, and how to choose the correct indicator for a specific titration. Students should be proficient in calculating concentrations and moles from given volumes and concentrations.

Hints

- Instead of a 500 mL volumetric flask, students could use a 250 mL flask. They would then use 15 mL of 2 M NaOH solution.
- It is a good idea to have some students use methyl orange indicator during the titration of NaOH with potassium hydrogen phthalate. This will clearly demonstrate bad results, which could be compared with the results obtained with the phenolphthalein.

Procedure A: STANDARDISATION OF 0.1 M NaOH SOLUTION

RESULTS

TABLE 1 SAMPLE RESULTS

Measurement	Flask A	Flask B	Flask C
mass of empty flask (g)	178.45	189.12	187.970
mass of flask + solid acid (g)	179.01	189.74	188.750
initial burette reading (mL)	0.00	3.4	0.00
final burette reading (mL)	23.5	29.8	32.8

Calculations

1 Table 2 shows the volume of sodium hydroxide solution used in each titration.

TABLE 2

Flask:	A	B	C
Volume of NaOH used (mL)	23.5	26.4	32.8

2 Table 3 shows the mass and number of moles of potassium hydrogen phthalate used in each titration.

TABLE 3

Flask:	A	B	C
Mass of $KHC_8H_4O_4$ (g)	0.560	0.620	0.780
Moles of $KHC_8H_4O_4$	2.7×10^{-3}	3.0×10^{-3}	3.8×10^{-3}

3 Table 4 shows the molar concentration of sodium hydroxide used in each titration.

TABLE 4

Flask:	A	B	C
Concentration of NaOH (M)	0.115	0.115	0.116
Average concentration of NaOH (M) = 0.115 M			

Discussion: PROCEDURE A

1 The weighing would not be accurate enough because solid sodium hydroxide absorbs moisture from the air and reacts with carbon dioxide in the air. This would increase the errors during titration.

2 Since the solution is being standardised against solid acid, it does not matter if the final concentration differs in the second or third decimal place. The concentration is accurately assessed.

3 The burette must contain an exact concentration of solution, as the final result depends upon this concentration and volume. The first rinsing will remove most of the moisture and impurities; all moisture and impurities are removed by the second rinse.
4 The titration involves a strong base and a weak acid ($KHC_8H_4O_4$). The equivalence point (neutralisation) is between pH 7 and pH 9, where the phenolphthalein indicator changes colour. All other indicators change colour at different pH ranges.
5 Measure 5 mL concentrated (10 M) HCl into a 500 mL volumetric flask half-filled with water. Fill the flask with water to the mark. Invert several times to mix thoroughly. Standardise this solution by titrating it against standard NaOH.

Procedure B: STANDARDISATION OF 0.1 M HCl SOLUTION

RESULTS TABLE 5 SAMPLE RESULTS

Conical flask	D	E	F
initial burette reading (mL)	0.0	1.7	3.6
final burette reading (mL)	24.7	26.5	28.2

Calculations

1 Table 6 shows the volume of sodium hydroxide solution used in each titration.

TABLE 6 SAMPLE RESULTS

Flask	D	E	F
Volume of NaOH used (mL)	24.7	24.8	24.6

2 Table 7 shows the number of moles of NaOH present in each flask, which is equal to the number of moles of HCl being neutralised.

TABLE 7 SAMPLE RESULTS

Conical flask	D	E	F
moles of NaOH used	2.84×10^{-3}	2.85×10^{-3}	2.82×10^{-3}

3 Table 8 shows the molar concentration of HCl for each flask.

TABLE 8 SAMPLE RESULTS

Flask	D	E	F
Concentration of HCl (M)	0.1135	0.114	0.1128
Average molar concentration of HCl solution (to three significant figures): 0.113 M			

Discussion: PROCEDURE B

1 The end point is observed in practice during a titration when the indicator changes colour, whereas the equivalence point is the theoretical end point of a titration, usually found by reading off the titration curve.
2 An accurate number of moles of acid were already transferred to the flask, and this number of moles is neutralised by the base. It is the number of moles in the flask that matters, not the concentration.
3 Yes. Phenolphthalein would be equally good as the titration involves strong acid with a strong base and the equivalence point is spread over a very large pH range of 3–10.
4 The concentration of 10 M HCl solution is only approximate. The concentrated acid is fuming acid—that is, a solution of hydrogen chloride gas in water, where some HCl gas is lost in the fumes. No matter how accurately we transfer an exact amount into the volumetric flask, it is never an exact concentration.
5 In analytical laboratories this is standard practice for volumetric analysis. It signifies the maximum accuracy with which the experimental results can be achieved.
6 Conical and volumetric flasks are used to prepare solutions for titrations, and water is routinely added to the conical flasks after the exact number of moles has been transferred. The concentration in the flasks does not matter at this stage. An accurate amount of solid or liquid is placed in the volumetric flask, which is then filled to the mark with water to obtain an accurate concentration. Pipettes and burettes transfer accurate concentrations of the original solutions, so they must not contain any traces of water or other impurities.

FOLLOW-UP

1 Number of moles of NaOH used:
$0.0153\ L \times 0.1107\ mol/L = 1.69 \times 10^{-3}$ mol
This is equivalent to the number of moles of aspirin in the conical flask, therefore:
1.69×10^{-3} mol × 180 g/mol = 0.304 g
2 a $NH_3(aq) + HCl(aq) \rightarrow NH_4^+(aq) + Cl^-(aq)$
b $25.0 \times M = 23.5 \times 0.1205$
M = 0.113 in diluted sample, or 1.13 M in original sample.

Sample risk assessment record

INVESTIGATION 31: Preparing standard solutions

Assessment team: ____________ Date: ____________ Year/group: *12*

Ref: *Heinemann Chemistry Practical Manual*

Chemicals used	Conc. (mol/L)	Amount	User code	DG class/ haz	Procedure as per Appendix D?	What are the hazards?
sodium hydroxide	2	30 mL	11-12	8/DHS	yes	Corrosive to skin and eyes, toxic if ingested
potassium hydrogen phthalate	solid	1 g	7-12	CW	yes	Slightly toxic if ingested
methyl orange	solution	6 drops	7-12	CW	yes	Toxic if ingested

Disposal of waste

All liquids can be washed down the sink, provided the pH is above 7.

How are risks controlled?

- wear safety glasses
- use gloves
- wash hands after use

Assessment of risk:

Risk for this investigation is **not significant**, provided appropriate control measures are in place as indicated above.

Approved by: ____________ Date: ____________

Investigation 32

Analysis of household acids and bases

Rationale

Students apply their titration skills to the analysis of household acids and bases, such as vinegar and household ammonia. They use their measured data to calculate the mass of ethanoic (acetic) acid in vinegar and the molar concentration of ammonia in two different brands of product.

Syllabus

Perform a first-hand investigation to determine the concentration of a commercial acidic or alkaline substance such as vinegar, orange juice or window cleaner.

Background knowledge

Students should know how to calculate moles and mass from given volumes and concentrations. In this investigation they are further developing their titration skills.

Hints

- Use the standard solutions prepared in Investigation 31.
- Use two different brands of household ammonia, or any other product containing ammonia.
- Different groups of students may use different brands of vinegar in order to compare them for acid concentration. A 10 mL sample only is recommended in case students encounter a brand that is fortified, in which case it may require a large amount of base.
- Dilute household ammonia should be dispensed from two class burettes, one for each brand. Do not use pipettes, as household ammonia foams and it is difficult to get rid of this foam inside the pipette.