30th International Chemistry Olympiad

Melbourne, Tuesday July 7, 1998

Laboratory Examination

Example Results and Marking Scheme

Official Version
**Laboratory Task 1 Results Sheet**

**Analysis of calcium/magnesium solution**

**Ca/Mg solution:** **Blue**  **Red**  **Green**  **Orange**  (circle one)

**Permanganate titration**

Concentration of standard KMnO₄: .................0.02039...................... M

<table>
<thead>
<tr>
<th>Titration number:</th>
<th>max 2 marks for at least two witnessed precipitates</th>
</tr>
</thead>
<tbody>
<tr>
<td>initial burette reading</td>
<td>0.90 0.80 3.00 mL</td>
</tr>
<tr>
<td>final burette reading</td>
<td>28.55 28.45 30.80 mL</td>
</tr>
<tr>
<td>volume of standard KMnO₄</td>
<td>27.65 27.65 27.80 mL</td>
</tr>
</tbody>
</table>

average titre = 27.70 mL ±0.07 mL av. dev. (ie ± 0.25% relative av. dev.)

In a 25 mL aliquot of dilute Ca/Mg solution:

\[
n(\text{KMnO}_4) \text{ required to titrate oxalate from dissolved calcium oxalate precipitate} = (0.0198 \text{ mol/L})(27.70 \text{ mL})/1000 \text{ mL/L} = 5.485 \times 10^{-4} \text{ mole}
\]

\[
n(\text{oxalate}) \text{ from dissolved calcium oxalate precipitate} = 5/2 \times 5.485 \times 10^{-4} \text{ mole} = 1.371 \times 10^{-3} \text{ mole}
\]

-1 mark for incorrect stoichiometry

\[
n(\text{Ca}^{2+}) \text{ from dissolved calcium oxalate precipitate} = n(\text{oxalate}) = 1.371 \times 10^{-3} \text{ mole}
\]

\[
[\text{Ca}] = (1000 \text{ mL/L}) 1.371 \times 10^{-3} \text{ mole} / 25.00 \text{ mL} = 0.0548 \text{ mol/L}
\]

In original Ca/Mg solution:

\[
[\text{Ca}] = 0.0548 \text{ mol/L} (1000 \text{ mL}) / 25.00 \text{ mL} = 0.548 \text{ mol/L}
\]

max 5 marks for correct calculation

Uncertainty in titre limits the uncertainty in [Ca] to 0.25% at least, or ±0.001 mol/L so 3 sig. figs at most. -1 mark for less than 3 sig figs, -2 marks for more than 4 sig figs

**Accuracy (max 13 marks)** - recalculated using student’s data

Sliding scale. 13.00 marks for 0 to 1.5% deviation, zero marks for greater than 15% deviation.

**Average concentration of Ca²⁺ in Ca/Mg solution:** ........0.548.... M

20 marks
Laboratory Task 2 Results Sheet

Standardisation of ~0.0125 M NaOH

Concentration of standard HCl in bottle: .................0.01253.................. M

<table>
<thead>
<tr>
<th>titration number:</th>
<th>1</th>
<th>2</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>aliquot of NaOH</td>
<td>25</td>
<td>25</td>
<td>25</td>
</tr>
<tr>
<td>initial burette reading</td>
<td>13.60</td>
<td>17.40</td>
<td>10.35</td>
</tr>
<tr>
<td>final burette reading</td>
<td>37.75</td>
<td>41.50</td>
<td>34.45</td>
</tr>
<tr>
<td>volume of standard HCl</td>
<td>24.15</td>
<td>24.10</td>
<td>24.10</td>
</tr>
</tbody>
</table>

average titre = 24.12 mL ±0.03 mL av. dev. (ie ± 0.12% relative av. dev.)

\[ [\text{NaOH}] = \frac{(0.01250 \text{ mol/L})(24.12 \text{ mL})}{(25.00 \text{ mL})} = 0.01206 \text{ mol/L} \]

Uncertainty is estimated few ppt so 4 sig. figs are justified.

-1 mark for less than 4 sig figs, -2 for more than 4 sig figs
-2 marks for incorrect calculation

Accuracy (max 5 marks) - recalculated using student's data

Sliding scale. 5.00 marks for 0 to 0.25% deviation, zero marks for greater than 5% deviation.

Average concentration of NaOH: ........... 0.01206.................. M

5 marks
Cobalt complex solution: **Blue**  **Red**  **Green**  **Orange**  (circle one)

Aliquot of cobalt complex solution used for ion-exchange: ..........25......... mL

<table>
<thead>
<tr>
<th>titration number:</th>
<th>1</th>
<th>2</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>initial burette reading</td>
<td>26.25</td>
<td>16.10</td>
<td>3.80</td>
</tr>
<tr>
<td>final burette reading</td>
<td>48.50</td>
<td>38.40</td>
<td>26.20</td>
</tr>
<tr>
<td>volume of ion-exchanged acid solution</td>
<td>22.25</td>
<td>22.30</td>
<td>22.40</td>
</tr>
</tbody>
</table>

**Calculations**

Average titre of eluted acid = 22.32 mL ±0.06 mL av. dev. (± 0.25% rel. av. dev.)

\[
\text{[H}^+\text{ collected in 100 mL vol flask]} \quad = \quad \frac{(0.01206 \text{ mol NaOH/L})(25.00 \text{ mL})}{(22.32 \text{ mL})} \quad = \quad 0.01351 \text{ mol/L}
\]

Total \(n(H^+)\) collected from column

\[
= \quad \frac{0.01351 \text{ mol/L}(100.0 \text{ mL})}{(1000 \text{ mL/L})} \quad = \quad 1.351 \times 10^{-3} \text{ mol}
\]

\(n(H^+)\) from aliquot put onto column

\[
= \quad \frac{0.00500 \text{ mol/L}(25.00 \text{ mL})}{(1000 \text{ mL/L})} \quad = \quad 1.250 \times 10^{-4} \text{ mol}
\]

-1 mark for neglect of \(HCl\)

\(n(H^+)\) ion-exchanged from complexes in aliquot put onto column

\[
= \quad 1.351 \times 10^{-3} \text{ mol} - 1.250 \times 10^{-4} \text{ mol} \quad = \quad 1.226 \times 10^{-3} \text{ mol}
\]

Let \(x\) = mass \([\text{Co(NH}_3\text{)}_5\text{NO}_2\text{]}\text{Cl}_2\) in 25.00 mL aliquot of mixture added to column

Mass of mixture added to column = \((25.00 \text{ mL/40 mL})(0.2000 \text{ g})\) = 0.1250 g

Then mass \([\text{Co(NH}_3\text{)}_6\text{]}\text{Cl}_3\) in aliquot = \((0.1250 - x)\) g

-1 mark for use of 0.2g only

\(n(H^+)\) ion-exchanged from \([\text{Co(NH}_3\text{)}_6\text{]}\text{Cl}_3\)

\[
= \quad 2 (x \text{ g}) / 261.00 \text{ g/mol} \quad = \quad 0.007663 x \text{ mol}
\]

-2 for more than 4 sig figs

\(n(H^+)\) ion-exchanged from \([\text{Co(NH}_3\text{)}_5\text{NO}_2\text{]}\text{Cl}_2\)

\[
= \quad 3 (0.1250 - x) \text{ g} / 267.50 \text{ g/mol}
\]

\(
= \quad (0.001402 - 0.011214 x) \text{ mol}
\]

-1 mark for neglect of cation charges

So \(0.007663 x + (0.001402 - 0.011214 x) = 0.001226\)

or \(x = 0.04956 \text{ g}\)

So \% \([\text{Co(NH}_3\text{)}_5\text{NO}_2\text{]}\text{Cl}_2\) = \(100 (0.04956 \text{ g} / 0.1250 \text{ g}) = 39.6\% \text{ w/w}\)

5 marks for correct calculation

**Accuracy (max 10 marks)** - recalculated using student’s data

Sliding scale. 10.00 marks for 0 to 2.00% deviation, zero marks for greater than 20% deviation.

Average percentage \([\text{Co(NH}_3\text{)}_5\text{NO}_2\text{]}\text{Cl}_2\) in sample: ... 39.6... % w/w

**15 marks**