RT · Redox titrations

Student notes - follow the slides, fill the blanks, work the questions

Goals: Explain titrant, analyte, titre, endpoint and equivalence. Use the mole ratio from a balanced redox equation to find an unknown concentration or mass. Scale an aliquot and predict which way an error moves a result.

Name: _____ Date: _____

Slide 1 of 9 · Two solutions, two jobs

A titration finds an unknown _____ by reacting a measured volume of one solution with a solution whose concentration is already known.

The solution in the buret is the _____. The solution in the flask is the _____, the one being analysed.

A good titration needs a reaction that goes _____ quickly, a visible change called the _____, and carefully measured volumes.

Use a _____ to deliver the analyte and a _____ to deliver the titrant. A graduated cylinder is less precise.

Example. A flask holds 25.00 mL of $Fe^{2+}(aq)$ of unknown concentration. A buret holds 0.0200 mol/L $MnO_4^-(aq)$. Which solution is the titrant, which is the analyte, and how does the known solution help find the unknown concentration?

Work:

Answer: _____

Try it. A buret holds 0.0150 mol/L $MnO_4^-(aq)$. A flask holds 10.00 mL of $Sn^{2+}(aq)$ of unknown concentration. Name the titrant and the analyte, and say which glassware should measure the 10.00 mL.

Work:

Answer: _____

Sketch (draw and label the diagram):

Slide 2 of 9 · Read the buret and use the trials

A buret is numbered from _____ at the top, so the readings get larger as liquid leaves.

The volume delivered is called the _____. It equals the final reading _____ the initial reading.

Read the curved surface, the _____, at eye level. For dark purple permanganate, read the _____ edge. Record _____ decimal places.

Repeat the titration and average only the trials that agree within the _____ the question states. For a limit of 0.20 mL, the largest and smallest trials kept may differ by at most _____.

Example. A buret has an initial reading of 0.40 mL and a final reading of 18.90 mL. Find the titre.

Work:

Answer: _____

Try it. Three trials give titres of 18.50 mL, 18.60 mL and 19.60 mL. Trials may differ by at most 0.20 mL from largest to smallest. Which trials do you average, and what is the average titre?

Work:

Answer: _____

Sketch (draw and label the diagram):

Slide 3 of 9 · The equation sets the mole ratio

The coefficients in a balanced equation count particles, so they also give the _____. In $MnO_4^- + 8H^+ + 5Fe^{2+} \rightarrow Mn^{2+} + 4H_2O + 5Fe^{3+}$, MnO_4^- to Fe^{2+} is _____.

Manganese goes from _____ to +2, so each MnO_4^- gains _____ electrons. Iron goes from +2 to +3, so each Fe^{2+} loses 1 electron.

Electrons lost must _____ electrons gained. That is why _____ Fe^{2+} ions are needed for each MnO_4^-, and the ratio is not 1 : 1.

E°reaction = E°(oxidizing agent) − E°(reducing agent), using values from the Data Booklet table printed on p. _____. A _____ result means the written direction is spontaneous. Acidified MnO_4^- or $Cr_2O_7^{2-}$ is usually the strongest oxidizing agent in a titration.

Example. Given in acidic solution: $MnO_4^- + 8H^+ + 5Fe^{2+} \rightarrow Mn^{2+} + 4H_2O + 5Fe^{3+}$. Give the mole ratio of Fe^{2+} to MnO_4^- and explain it with electrons. Then find E°reaction using $E°(MnO_4^-/Mn^{2+}) = +1.51$ V and $E°(Fe^{3+}/Fe^{2+}) = +0.77$ V.

Work:

Answer: _____

Try it. Given in acidic solution: $5H_2C_2O_4 + 2MnO_4^- + 6H^+ \rightarrow 10CO_2 + 2Mn^{2+} + 8H_2O$. Give the mole ratio of $H_2C_2O_4$ to MnO_4^-. Each carbon atom in $H_2C_2O_4$ goes from +3 to +4. How many electrons does one $H_2C_2O_4$ lose?

Work:

Answer: _____

Slide 4 of 9 · Endpoint: a faint pink that stays

MnO_4^- ions are deep _____. Mn^{2+} ions at 0.010 mol/L are _____, and pale pink at 1.0 mol/L (Data Booklet, p. 11).

Before the reaction is complete, Fe^{2+} reduces each drop of MnO_4^-, so the purple of the drop _____. The acid in the flask supplies the _____ in the equation.

When all the Fe^{2+} has reacted, the next drop leaves a faint pink-purple colour that _____. This is the _____, and permanganate needs no extra indicator.

Equivalence is calculated, and the endpoint is _____. A deep pink means the titre is too _____.

Example. A permanganate solution is added from a buret to $Fe^{2+}(aq)$ in a flask. What does the flask look like before the reaction is complete, and what tells you to stop?

Work:

Answer: _____

Try it. A student keeps adding permanganate until the flask is deep pink. Is the titre too large, too small or correct? Explain.

Work:

Answer: _____

Slide 5 of 9 · The titration calculation

Concentration is moles per litre, so change every volume from mL to L first. Divide by _____. For example, 18.50 mL = _____ L.

The plan is moles of titrant, then the _____, then moles of analyte, then _____.

Moles of titrant: n = _____, where c is concentration in mol/L and V is volume in _____.

Write the ratio fraction with the _____ substance on top. Divide the moles of analyte by the _____ volume, never by the titre.

Example. Given the equation $MnO_4^- + 8H^+ + 5Fe^{2+} \rightarrow Mn^{2+} + 4H_2O + 5Fe^{3+}$. A 25.00 mL sample of $Fe^{2+}(aq)$ is titrated with 0.0200 mol/L $MnO_4^-(aq)$. The average titre is 18.50 mL. Find $c(Fe^{2+})$ in mol/L.

Work:

Answer: _____

Try it. Given the same equation. A 20.00 mL sample of $Fe^{2+}(aq)$ is titrated with 0.0250 mol/L $MnO_4^-(aq)$. The average titre is 16.80 mL. Find $c(Fe^{2+})$ in mol/L.

Work:

Answer: _____

Slide 6 of 9 · Method: how to do a redox titration calculation

Step 1. _____ the trials that agree within the limit.

Step 2. Change _____ to _____ by dividing by 1000.

Step 3. Find n = _____ for the solution you know.

Step 4. Use the mole _____ from the balanced equation, with the wanted substance on top.

Step 5. Find the unknown with c = n ÷ V. Use the volume of the _____ in the flask.

Check: multiply back. c × V must give the _____ you found.

Example. Use the method on 25.00 mL of $Fe^{2+}(aq)$ titrated with 0.0200 mol/L $MnO_4^-(aq)$. The average titre is 18.50 mL. The equation is $MnO_4^- + 8H^+ + 5Fe^{2+} \rightarrow Mn^{2+} + 4H_2O + 5Fe^{3+}$. Find $c(Fe^{2+})$.

Work:

Answer: _____

Try it. Use the method on 20.00 mL of a Fe^{2+} solution that needs 15.00 mL of 0.0200 mol/L MnO_4^- with the same equation. Find $c(Fe^{2+})$.

Work:

Answer: _____

Slide 7 of 9 · Your turn: a different ratio

The steps are the same for every titration, but the ratio comes from the _____.

In $5H_2C_2O_4 + 2MnO_4^- + 6H^+ \rightarrow 10CO_2 + 2Mn^{2+} + 8H_2O$, $H_2C_2O_4$ to MnO_4^- is _____, so we multiply by _____.

The ratio goes from the _____ substance to the _____ substance, with the coefficient of the wanted substance on top.

Two common slips are a wrong ratio and an upside-down _____. Check by multiplying the answer by the flask _____.

Example. Given $5H_2C_2O_4 + 2MnO_4^- + 6H^+ \rightarrow 10CO_2 + 2Mn^{2+} + 8H_2O$. A 20.00 mL sample of $H_2C_2O_4(aq)$ needs 16.30 mL of 0.0150 mol/L $MnO_4^-(aq)$ to reach the endpoint. Find $c(H_2C_2O_4)$ in mol/L.

Work:

Answer: _____

Try it. Given the same equation. A 25.00 mL sample of $H_2C_2O_4(aq)$ needs 14.50 mL of 0.0120 mol/L $MnO_4^-(aq)$ to reach the endpoint. Find $c(H_2C_2O_4)$ in mol/L.

Work:

Answer: _____

Slide 8 of 9 · An aliquot from a larger solution

A measured part of a larger solution is called an _____. The moles found by titrating it are the moles in the _____ only.

Whole ÷ part = whole volume ÷ _____. Here 100.0 mL ÷ 20.00 mL = _____.

The whole solution has the _____ concentration, so it holds _____ times the moles of the aliquot.

Mass = n × M, where M is molar mass in _____. Mass percent = mass of iron ÷ _____ × 100.

Example. An iron tablet of mass 0.800 g is dissolved and made up to 100.0 mL of $Fe^{2+}(aq)$. A 20.00 mL aliquot needs 14.10 mL of 0.0200 mol/L $MnO_4^-(aq)$. The equation is $MnO_4^- + 8H^+ + 5Fe^{2+} \rightarrow Mn^{2+} + 4H_2O + 5Fe^{3+}$. Find the mass of iron in the tablet and the mass percent of iron (Fe: 55.85 g/mol).

Work:

Answer: _____

Try it. Given the same equation. An iron tablet of mass 0.500 g is dissolved and made up to 250.0 mL of $Fe^{2+}(aq)$. A 25.00 mL aliquot needs 13.40 mL of 0.0100 mol/L $MnO_4^-(aq)$. Find the mass of iron in the tablet and the mass percent of iron (Fe: 55.85 g/mol).

Work:

Answer: _____

Slide 9 of 9 · Which way does an error push the answer?

Follow the chain. The titre sets the moles of _____, which set the moles of analyte, which set the _____.

Adding too much titrant makes the titre too _____, so the calculated c(Fe^{2+}) is too _____.

A buret rinsed with water makes the titrant weaker, so more volume is needed and the titre is too large. The calculation still uses the _____ concentration, so c is too high.

A wet flask adds no moles of Fe^{2+}, so the result is _____. For each error, mark every step larger, smaller or unchanged.

Example. A student rinses the buret with water, then fills it with 0.0200 mol/L MnO_4^-(aq) and titrates Fe^{2+}(aq). Is the calculated c(Fe^{2+}) too high, too low or unchanged? Follow the chain.

Work:

Answer: _____

Try it. A student stops the titration just before the faint pink colour appears. Is the calculated c(Fe^{2+}) too high, too low or unchanged? Follow the chain.

Work:

Answer: _____

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Redox titrations | Questions 1-2 of 7

1. Given buret readings: initial 2.15 mL and final 21.85 mL. Find the titre.

Work:

Final answer (with unit): _____

2. Given $MnO_4^- + 8H^+ + 5Fe^{2+} \rightarrow Mn^{2+} + 4H_2O + 5Fe^{3+}$. A 25.00 mL sample of $Fe^{2+}(aq)$ needs 22.40 mL of 0.0150 mol/L $MnO_4^-(aq)$. Find $c(Fe^{2+})$ in mol/L.

Work:

Final answer (with unit): _____

RT · Practice

Redox titrations | Questions 3-4 of 7

3. Given $5H_2C_2O_4 + 2MnO_4^- + 6H^+ \rightarrow 10CO_2 + 2Mn^{2+} + 8H_2O$. A 10.00 mL sample of $H_2C_2O_4(aq)$ needs 12.60 mL of 0.0200 mol/L $MnO_4^-(aq)$. Find $c(H_2C_2O_4)$ in mol/L.

Work:

Final answer (with unit): _____

4. Given $MnO_4^- + 8H^+ + 5Fe^{2+} \rightarrow Mn^{2+} + 4H_2O + 5Fe^{3+}$. A 10.00 mL aliquot from a 250.0 mL flask of $Fe^{2+}(aq)$ needs 15.60 mL of 0.0100 mol/L $MnO_4^-(aq)$. Find the mass of iron in the whole flask (Fe: 55.85 g/mol, Alberta Chemistry 30 Data Booklet).

Work:

Final answer (with unit): _____

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Redox titrations | Questions 5-6 of 7

5. A student reads the final buret reading 0.50 mL too large in a permanganate titration of Fe^{2+}. Is the calculated $c(Fe^{2+})$ too high, too low or unchanged? Explain with the chain of calculation.

Work:

Final answer (with unit): _____

6. Explain why a permanganate titration of iron(II) needs no added indicator, and describe the endpoint colour.

Work:

Final answer (with unit): _____

RT · Practice

Redox titrations | Questions 7-7 of 7

7. Challenge: Given $Cr_2O_7^{2-} + 14H^+ + 6Fe^{2+} \rightarrow 2Cr^{3+} + 7H_2O + 6Fe^{3+}$. An iron sample is dissolved and made up to 100.0 mL. A 20.00 mL aliquot needs 14.80 mL of 0.0100 mol/L $Cr_2O_7^{2-}(aq)$. Find the mass of iron in the whole sample, in grams, to three significant digits (M(Fe) = 55.85 g/mol, from the Data Booklet).

Work:

Final answer (with unit): _____