Past-paper walk-through

Redox processes: electron transfer and changes in oxidation number (oxidation state) ▪ 6.1

title_zh: 氧化还原过程：电子转移与氧化数（氧化态）的变化

eXercise

Questions in this set

- 9701/11 N25 Q9 ▪ 1 mark
- 9701/11 N25 Q10 ▪ 1 mark
- 9701/12 N25 Q3 ▪ 1 mark
- 9701/12 N25 Q11 ▪ 1 mark
- 9701/14 N25 Q11 ▪ 1 mark
- 9701/22 N25 Q1 ▪ 10 marks
- 9701/34 J25 Q1 ▪ 14 marks

Reading the mark scheme

- **B1** a mark that stands on its own – the point is either made or not.
- **M1** a *method* mark: the right approach, even if the number is wrong.
- **A1** an *answer* mark, and it usually needs its M mark first.
- **C1** a working mark on the way to the answer.
- // separates answers the examiner accepts equally.
- **ecf** = error carried forward: a later part is marked on your own earlier answer.
- **owtte** = "or words to that effect" – the wording need not match.

Question 9

9701/11 N25 ▪ Q9 ▪ 1 mark

9 Sulfite ions, SO_3^{2-}, react separately with zinc and with manganese dioxide.

a, *b*, *c*, *d*, *w*, *x*, *y* and *z* are all whole numbers.

$$a SO_3^{2-}(aq) + b H_2O(l) + Zn(s) \rightarrow Zn^{2+}(aq) + c OH^-(aq) + d S_2O_4^{2-}(aq)$$

$$MnO_2(s) + w SO_3^{2-}(aq) + x H^+(aq) \rightarrow Mn^{2+}(aq) + y S_2O_6^{2-}(aq) + z H_2O(l)$$

Which numbers are correct for *a*, *b*, *w* and *x*?

	a	*b*	*w*	*x*
A	1	2	2	4
B	2	2	2	4

Question 9

C	1	2	4	2
D	2	2	4	2

Solution 9

Answer: **B**

Why

- Two SO_3^{2-} are needed to build one $S_2O_4^{2-}$, so $a = 2$; balancing oxygen then gives $b = 2$.
- Likewise two SO_3^{2-} make one $S_2O_6^{2-}$, so $w = 2$.
- Balancing charge in the second equation gives $x = 4$.

Question 10

9701/11 N25 ▪ Q10 ▪ 1 mark

10 Which equation shows hydrogen acting as an oxidising agent?

A $H_2 + 2K \rightarrow 2K^+H^-$

B $H_2 + I_2 \rightarrow 2HI$

C $H_2 + Cu_2S + ZnO \rightarrow 2Cu + ZnS + H_2O$

D $3H_2 + N_2 \rightarrow 2NH_3$

Solution 10

Answer: **A**

Why

- An oxidising agent is itself reduced, so hydrogen's oxidation number must *fall*.
- In K^+H^- hydrogen is -1, down from 0 in H_2 – it has been reduced.
- In the other three hydrogen ends up at $+1$, so there it is the reducing agent.

Question 3

9701/12 N25 ▪ Q3 ▪ 1 mark

3 The reaction of hydrogen sulfide with sulfur dioxide gives sulfur as one of the products.

The two relevant redox equations are shown.

$$H_2S(aq) \rightleftharpoons S(s) + 2H^+(aq) + 2e^-$$

$$SO_2(aq) + 4H^+(aq) + 4e^- \rightleftharpoons S(s) + 2H_2O(l)$$

How many moles of hydrogen sulfide are needed to react with sulfur dioxide to produce 1 mol of sulfur?

A $\frac{1}{3}$ mol **B** $\frac{2}{3}$ mol **C** $\frac{3}{2}$ mol **D** 2 mol

Solution 3

Answer: **B**

Why

- Balance the electrons: two H_2S half-equations ($4e^-$) match one SO_2 half-equation.
- That gives $2H_2S + SO_2 \rightarrow 3S + 2H_2O$.
- So 3 mol of sulfur needs 2 mol of H_2S, and 1 mol needs $\frac{2}{3}$ mol.

Question 11

9701/12 N25 ▪ Q11 ▪ 1 mark

11 In which substance is the average oxidation number of sulfur the highest?

A S_8 **B** $Na_2S_4O_6$ **C** $Na_2S_2O_3$ **D** SO_2Cl_2

Solution 11

Answer: **D**

Why

- S_8 is an element, so sulfur is 0.
- $Na_2S_4O_6$: $2(+1) + 4x + 6(-2) = 0$ gives $x = +2.5$; $Na_2S_2O_3$ gives $+2$.
- SO_2Cl_2: $x - 4 - 2 = 0$ gives $x = +6$, the highest of the four.

Question 11

9701/14 N25 ▪ Q11 ▪ 1 mark

11 Acidified potassium manganate(VII) reacts with iron(II) ethanedioate, FeC_2O_4.

The reactions taking place are shown.

$$MnO_4^- + 8H^+ + 5e^- \rightarrow Mn^{2+} + 4H_2O$$

$$Fe^{2+} \rightarrow Fe^{3+} + e^-$$

$$C_2O_4^{2-} \rightarrow 2CO_2 + 2e^-$$

How many moles of iron(II) ethanedioate react with **one** mole of potassium manganate(VII)?

A 0.60 **B** 1.67 **C** 2.50 **D** 5.00

Solution 11

Answer: **B**

Why

- One MnO_4^- accepts 5 electrons.
- Each FeC_2O_4 supplies 3: one from $Fe^{2+} \rightarrow Fe^{3+}$ and two from $C_2O_4^{2-} \rightarrow 2CO_2$.
- So $5/3 = 1.67$ mol of iron(II) ethanedioate per mole of manganate(VII).

Question 1

9701/22 N25 ▪ Q1 ▪ 10 marks

1 Manganese, Mn, and its compounds are widely used in many chemical reactions.

(a) Mn is usually found as a single isotope, manganese-55.

(i) Determine the number of protons, neutrons and electrons in an atom of manganese-55.

Question 1

[1]

(ii) Define isotopes.

Question 1

(iii) A sample of manganese from the Moon is found to contain manganese-53 in addition to manganese-55.

State the two pieces of information needed to determine the relative atomic mass, A_r, of manganese in this sample.

Question 1

Question 1

[2]

(b) The shorthand electronic configuration of manganese is [Ar] $3d^5\ 4s^2$.

(i) Complete the full electronic configuration of manganese.

..... $3d^5\ 4s^2$ [1]

(ii) Deduce the total number of unpaired electrons in an atom of manganese.

Question 1

(c) Manganese(IV) oxide reacts with methanal, CH_2O, in acidic conditions to produce carbon dioxide. The movement of electrons to or from relevant species is shown in the following half-equations.

half-equation 1 $\quad CH_2O + H_2O \rightarrow CO_2 + 4H^+ + 4e^-$

half-equation 2 $\quad MnO_2 + 4H^+ + 2e^- \rightarrow Mn^{2+} + 2H_2O$

(i) Identify the species that is reduced in half-equation 2. Explain your answer.

Question 1

(ii) The oxidation state of carbon in methanal is 0.

Calculate the oxidation state of carbon in carbon dioxide.

Question 1

(iii) Construct the ionic equation for the reaction of manganese(IV) oxide with methanal in acidic conditions.

Question 1

[Total: 10]

Solution 1

(a)(i)

Mark scheme

- 25 protons 30 neutrons 25 electrons
- 1

(a)(ii)

Mark scheme

- (atoms of an element) with the same number of protons and different number of neutrons
- 1

Solution 1

(a)(iii)

Mark scheme

- M1 (relative) isotopic mass.
- OR (relative isotopic) mass of Mn-55 and Mn-53 M2
- (relative) abundance of each isotope
- 2

Solution 1

(b)(i)

Mark scheme

- 1s2 2s2 2p6 3s2 3p6 (3d5 4s2)
- 1

(b)(ii)

Mark scheme

- 5
- 1

Solution 1

(c)(i)

Mark scheme

- Mn / MnO2 AND it gains electrons
- 1

(c)(ii)

Mark scheme

- (+)4
- 1

Solution 1

(c)(iii)

Mark scheme

- Due to an issue with question 1(c)(iii), the question has been removed from the question paper.
- N/A

Question 1

9701/34 J25 ▪ Q1 ▪ 14 marks

Iron is an element that is essential in the human diet. Some people need to take iron supplement tablets to ensure an adequate intake of iron.
You will investigate the mass of iron in an iron supplement tablet by titrating a solution with potassium manganate(VII).

$$Fe^{2+}(aq) \rightarrow Fe^{3+}(aq) + e^{-}$$

$$MnO_4^{-}(aq) + 8H^{+}(aq) + 5e^{-} \rightarrow Mn^{2+}(aq) + 4H_2O(l)$$

FB 1 is an aqueous solution of iron supplement tablets made by dissolving 14 tablets in 1.00dm^3 of solution. The iron in each tablet is iron(II) sulfate, $FeSO_4 \cdot 7H_2O$. **FB 2** is 0.0100mol dm^{-3} acidified aqueous potassium manganate(VII), $KMnO_4$. **FB 3** is dilute sulfuric acid, H_2SO_4.

Question 1

(a) Method

- Fill a burette with **FB 2**.
- Pipette 25.0cm^3 of **FB 1** into a conical flask.
- Use the 25cm^3 measuring cylinder to add 10.0cm^3 of **FB 3** to the conical flask.
- Perform a rough titration and record your burette readings in the space below.

The rough titre is ___ cm^3.

- Carry out as many accurate titrations as you think necessary to obtain consistent results.
- Make sure any recorded results show the precision of your practical work.
- Record, in a suitable form in the space below, all your burette readings and the volume of **FB 2** added in each accurate titration.

Question 1

Rinse the burette with distilled water and leave to drain while you continue Question 1.

Results **[7]**

Question 1

I	
II	
III	
IV	
V	
VI	
VII	

[7]

Question 1

9701/34 J25 ▪ Q1 ▪ 14 marks

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Question 1

(b) From your accurate titration results, calculate a suitable mean value to use in your calculations. Show clearly how you obtain the mean value.

25.0 cm^3 of **FB 1** required cm^3 of **FB 2**. **[1]**

Question 1

9701/34 J25 ▪ Q1 ▪ 14 marks

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Question 1

(c)(i) Give your answers to **(c)(ii)**, **(c)(iii)** and **(c)(iv)** to an appropriate number of significant figures. **[1]**

(c)(ii) Calculate the amount, in mol, of manganate(VII) ions in the volume of **FB 2** in **(b)**. **[1]**

(c)(iii) Use your answer to **(c)(ii)** and the equations at the start of the question to calculate the concentration, in mol dm^{-3}, of iron(II) ions in **FB 1**. **[1]**

(c)(iv) Use your answer to **(c)(iii)** to calculate the concentration, in g dm^{-3}, of iron(II) ions in **FB 1**. **[1]**

(c)(v) The manufacturer of the iron supplement tablets used to make **FB 1** claims that each tablet contains a minimum of 150 mg of Fe^{2+}.

Use your answer to **(c)(iv)** and the information given about **FB 1** to determine whether this claim is correct. Show your working. **[1]**

Question 1

9701/34 J25 ▪ Q1 ▪ 14 marks

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Question 1

(d) A student used all the **FB 3** and suggests that dilute hydrochloric acid would be a suitable replacement. Suggest whether the student is correct or not. Explain your answer. **[1]**

Solution 1

(a) Mark scheme

I All the following data recorded.

- two burette readings **AND** titre for the rough titration
- initial and final readings for **two** (or more) accurate titrations

II Titre values recorded for accurate titrations, **AND** correct headings and units in the accurate titration table

- initial / start **AND** (burette) reading / volume
- final / end **AND** (burette) reading / volume
- titre **OR** volume used / added **OR** FB 2 used / added
- unit: / cm^3 **OR** (cm^3) **OR** in cm^3 (for each heading) **OR** cm^3 unit given for each volume recorded.

Solution 1

III All accurate burette readings recorded to 0.05 cm^3. **IV** The final accurate titre recorded must be within 0.10 cm^3 of any other accurate titre.
Accuracy (Q) marks Round burette readings to the nearest 0.05 cm^3. Check and correct titre subtractions where necessary. Select the best mean titre, using the following hierarchy:

- two (or more) accurate identical titres (ignoring any that are labelled "rough"), *then*
- two (or more) accurate titres within 0.05 cm^3, *then*
- two (or more) accurate titres within 0.10 cm^3, *etc.*

Solution 1

Calculate the Supervisor's mean titre to two decimal places. Calculate the Candidate's mean titre to two decimal places. Calculate the difference (δ) between the Supervisor's and Candidate's mean titre.
Award accuracy Q marks as follows: **V** award if $\delta \leq 0.50$ cm^3 **VI** award if $\delta \leq 0.30$ cm^3 **VII** award if $\delta \leq 0.20$ cm^3

Solution 1

(b)

Mark scheme

Correct calculation of the mean titre

- Candidate must take the average of two (or more) titres that are within a total spread of not more than 0.20 cm^3.
- Working/explanation must be shown OR ticks must be put next to the two (or more) accurate readings selected.
- The mean should be quoted to 2 d.p. and be rounded to nearest 0.01 cm^3 (e.g. 26.675 cm^3 must be rounded to 26.68 cm^3).

Solution 1

(c)(i)

Mark scheme

- Final answers for (c)(ii), (c)(iii) and (c)(iv) to 3 or 4 significant figures.

(c)(ii)

Mark scheme

- Correctly calculates
- amount of manganate(VII) $= 0.01 \times \frac{\text{volume in (b)}}{1000}$ mol

Solution 1

(c)(iii)

Mark scheme

- Correctly uses
- amount of Fe^{2+} reacting with FB 2 = (c)(ii) $\times$ 5 mol
- AND concentration of Fe^{2+} = ((c)(ii) $\times$ 5) $\times$ 40 mol dm^{-3}

Solution 1

(c)(iv)

Mark scheme

- Correctly uses
- concentration of Fe^{2+} = (c)(iii) $\times$ 55.8 g dm^{-3}

Solution 1

(c)(v)

Mark scheme

- Conclusion
- yes / correct (because)
- AND (c)(iv) $\times$ 1000 / 14 (> 150 claimed as present in tablet)

Solution 1

(d)

Mark scheme

- no because chloride (ions) are oxidised by manganate(VII) / $KMnO_4$.
- OR no because hydrochloric acid is monoprotic AND might not produce enough H^+.
- OR yes because hydrochloric acid is a strong acid.