

6.1 REDOX PROCESSES

Learning outcomes

Candidates should be able to:

1. calculate oxidation numbers of elements in compounds and ions
2. explain and use the terms redox, oxidation, reduction and disproportionation in terms of electron transfer and changes in oxidation number
3. explain and use the terms oxidising agent and reducing agent
4. use changes in oxidation numbers to help balance chemical equations
5. use a Roman numeral to indicate the magnitude of the oxidation number of an element

Introduction

The modern definition of **oxidation**, is the **removal of electrons** from a substance, while **reduction** is the **addition of electrons** to a substance.

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Calculation of oxidation numbers

Oxidation state shows the total number of electrons which have been removed from an element (a positive oxidation state) or added to an element (a negative oxidation state) to get to its present state.

Rules for calculation of oxidation numbers:

- The oxidation number of atoms in a pure element is 0.
- In a compound, the more electronegative element is given a negative oxidation number (fluorine always has oxidation number -1).
- The sum of all the oxidation numbers in a molecule is 0.
- The sum of the oxidation states of all the atoms in an ion is equal to the charge on the ion.
- In most compounds, the oxidation number of oxygen is -2 and that of hydrogen is $+1$.
- Oxidation numbers of group 1 elements is always $+1$ in their combined state.
- Oxidation numbers of group 2 elements is always $+2$ in their combined states.
- Oxidation numbers of fluorine is always -1 in the combined state.
- Oxidation number of halogens is -1 in most of the compounds.

Oxidation involves an **increase in oxidation state**

Reduction involves a **decrease in oxidation state**

1. The peroxide ion is O_2^{2-} .
Deduce the average oxidation number of oxygen atoms in the peroxide ion. [1]
2. State the oxidation number of phosphorus in P_4O_{10} . [1]
3. Determine the oxidation number of P in H_3PO_3 . [1]

4. The chlorides of some of the Period 3 elements are shown in Table 2.1.

Period 3 chloride	NaCl	AlCl ₃	SiCl ₄	PCl ₅	PCl ₃	SCl ₂
bonding					C	C
structure					S	S
oxidation state of Period 3 element						

Complete Table 2.1.

- Identify the bonding shown by each chloride under standard conditions.

Use C = covalent, I = ionic, M = metallic.

- Identify the structure shown by each chloride under standard conditions.

Use G = giant, S = simple.

- Deduce the oxidation state of the Period 3 element in each chloride.

[4]

5. The oxide of silicon reacts with calcium oxide in an addition reaction to produce calcium silicate, CaSiO₃. The oxidation number of calcium in CaSiO₃ is +II.

- (i) Deduce the oxidation number of silicon in calcium silicate.

oxidation number of silicon

[1]

1. What is the average oxidation number of sulfur in each compound?

	Ca(HSO ₃) ₂	Na ₂ S ₂ O ₃
A	4	2
B	4	4
C	6	2
D	6	4

2. Which particle contains nitrogen in the same oxidation state as in the ion N₂O₂²⁻?

A NH₂F

B N₂O₄

C NO₃⁻

D HNF₂

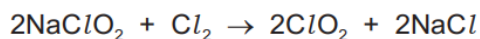
3. Solutions containing chlorate (I) ions are used as household bleaches and disinfectants. These solutions decompose on heating as shown.



Which oxidation states are shown by chlorine in these three ions?

	ClO ⁻	ClO ₃ ⁻	Cl ⁻
A	+1	+3	-1
B	-1	+3	+1
C	+1	+5	-1
D	-1	+5	+1

6. ClO_2 can be prepared by reacting NaClO_2 with Cl_2 .



oxidation state of chlorine:

+3

Write the oxidation state of chlorine in each species in the boxes provided.

[2]

7. What are the oxidation numbers of manganese in this equation?



8. State the oxidation number of the Period 3 elements bonded to Cl in NaCl and PCl_5 .
Explain the difference in the oxidation number.

.....

.....

..... [2]

9. Chlorine is a reactive element. It forms many compounds.

- (i) Complete Table 2.1 to show the maximum oxidation number of the elements Na to P in their chlorides. [1]

element	Na	Mg	Al	Si	P	S	Cl
maximum oxidation number							

- (ii) State what determines the maximum oxidation number of elements in period 3.

[1]

10. A sample of Al reacts with an excess of Cl_2 .

- (i) State the oxidation number of Al in the product of the reaction.

oxidation number of Al [1]

- (ii) State what determines the maximum oxidation number of the Period 3 elements in their oxides.

[1]

11. Aluminium chloride and phosphorus chloride are both white solids.

- (i) State the maximum oxidation number of aluminium and of phosphorus in these solid chloride salts.

maximum oxidation number of aluminium

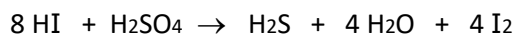
maximum oxidation number of phosphorus

[1]

- (ii) State why the maximum oxidation number of aluminium is different from that of phosphorus.

[1]

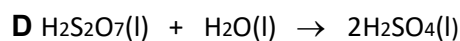
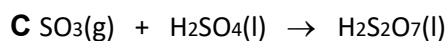
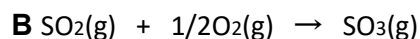
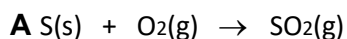
4. When hydrogen iodide is reacted with concentrated sulfuric acid, several reactions occur, including:



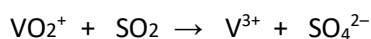
Which row gives the change in oxidation number of iodine and of sulfur in this reaction?

	change in oxidation number of iodine	change in oxidation number of sulfur
A	-1	+6
B	-1	+8
C	+1	-6
D	+1	-8

5. In which reaction does the greatest change in the oxidation number of sulfur occur?

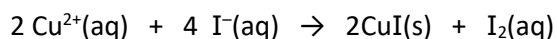


6. In the redox reaction shown, how do the oxidation states of vanadium and sulfur change?



	vanadium		sulfur	
	from	to	from	to
A	+1	+3	0	-2
B	+1	+3	+4	+6
C	+5	+3	0	-2
D	+5	+3	+4	+6

7. The equation for the reaction between aqueous copper ions and aqueous iodide ions is as follows.



What is the change in oxidation state of copper?

A +2 to -1

B +2 to 0

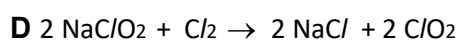
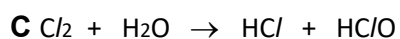
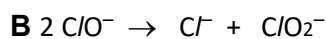
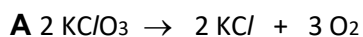
C +2 to +1

D +4 to +2

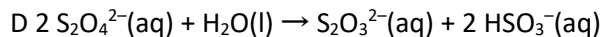
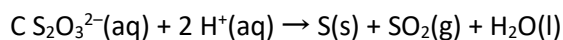
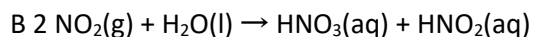
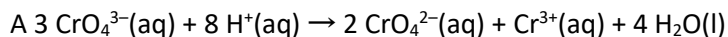
8. In which row do the oxidation numbers of vanadium increase?

	smallest	largest
A	VO_4^{3-}	VO_3^{-} VO_2^{+}
B	VO^{2+}	V_2O_3 VO_4^{3-}
C	V_2O_3	VO^{2+} VO_3^{-}
D	VO_4^{3-}	VO_2^{+} VO_2^{+}

9. In which reaction does the oxidation number of chlorine change by the largest amount?



10. In this question, the average oxidation state of sulfur in $\text{S}_2\text{O}_3^{2-}$ and sulfur in $\text{S}_2\text{O}_4^{2-}$ should be used.
In which reaction does the underlined element have the largest increase in oxidation state?



11. In a catalytic converter in the exhaust system of a car, carbon monoxide is oxidised to carbon dioxide, and nitrogen monoxide is reduced to nitrogen.

What are the changes in oxidation number of carbon and nitrogen in these two processes?

	carbon	nitrogen
A	-2	+2
B	-1	+1
C	+1	-1
D	+2	-2

12. Ammonium ions are converted into nitrate ions by bacteria.

What is the change in the oxidation number of nitrogen?

A -8

B +2

C +8

D -2

13. In the treatment of domestic water supplies, chlorine is added to water to kill bacteria. Some ClO^- ions are formed.
What is the change in oxidation number of chlorine when forming the ClO^- ion from aqueous chlorine?

A -1

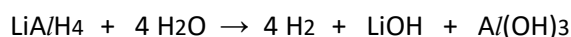
B 0

C +1

D +2

14. LiAlH_4 contains AlH_4^- ions in which aluminium has an oxidation state of +3.

LiAlH_4 reacts with water, as shown.



In this reaction, each of the four water molecules produces one hydroxide ion. It does this by losing one H^+ ion, which reacts with the LiAlH_4 .

Which changes in oxidation number occur in this reaction?

A Al increases by 1 and H decreases by 1.

B H decreases by 2 and also increases by 1.

C H increases by 1 and also decreases by 1.

D O decreases by 1 and H increases by 1.

15. The compound potassium bismuthate(V), KBiO_3 , is a powerful oxidising agent. What is the significance of the (V) in potassium bismuthate(V)?

A It is the oxidation number of the bismuth atom.
 B It is the charge of the bismuthate ion.
 C It is the oxidation number of the bismuthate ion.
 D It is the sum of the charges of the two ions present.

Redox reactions

Oxidation and reduction always take place together. We call the reactions in which this happens **redox reactions**.

An **oxidising agent** brings about oxidation by removing electrons from another atom or ion.

A **reducing agent** brings about reduction by donating electrons to another atom or ion.

Summary

Oxidation	Reduction
Loss of electrons	Gain of electrons
Gain of oxygen	Loss of oxygen
Loss of hydrogen	Gain of hydrogen
Increase in oxidation state	Decrease in oxidation state

12. HI reacts with oxygen to form iodine and water.

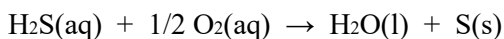
(i) Construct an equation for the reaction of HI with oxygen.

[1]

(ii) Explain, with reference to oxidation numbers, why this reaction is a redox reaction.

[2]

13. $\text{H}_2\text{S}(\text{aq})$ reacts slowly with oxygen dissolved in water. The reaction is represented by the following equation.



Explain, with reference to oxidation numbers, why this reaction is a redox reaction.

[2]

14. When magnesium is heated in air, magnesium oxide, MgO , is the major product. Smaller amounts of magnesium nitride, Mg_3N_2 , are also made.

(i) Calculate the oxidation number for magnesium and for the nitrogen species in Mg_3N_2 to complete the following table.

[1]

species	magnesium in Mg_3N_2	nitrogen in Mg_3N_2
oxidation number		

(ii) Identify the type of reaction which takes place between magnesium and nitrogen. Explain your answer.

[1]

15. The equation shown below describes the reaction which occurs when aqueous potassium iodide is added to aqueous copper(II) sulfate. A white precipitate of copper(I) iodide forms in a brown solution of iodine and potassium sulfate.



The table gives the oxidation numbers of iodine in the different species in the equation.

iodine-containing species	oxidation number of iodine
KI	-1
CuI	-1
I_2	0

(i) Deduce the oxidation number of copper in CuSO_4 and CuI.

●● oxidation number of copper in CuSO_4

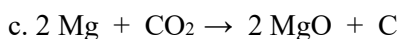
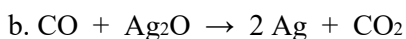
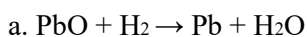
●● oxidation number of copper in CuI

[1]

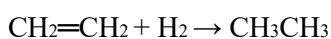
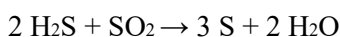
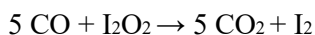
(ii) Describe the type of reaction shown above. Explain your answer in terms of electron transfer.

[2]

16. In each of the following equations, state which reactant has been oxidised:



In each of the following equations, state which reactant has been reduced:

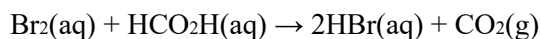


17. Na reacts with O₂ to form Na₂O. Na is the reducing agent in this reaction.
Define reducing agent. [1]

18. Potassium chlorate, KClO₃, is widely used as an oxidising agent and to make O₂(g).
Define oxidising agent. [1]

19. Explain the term oxidising agent. [1]

20. Aqueous bromine reacts with methanoic acid to form hydrogen bromide and carbon dioxide gas.



The table shows the oxidation numbers of bromine and carbon in the species involved in this reaction.

	Br in Br ₂	C in HCO ₂ H	Br in HBr	C in CO ₂
oxidation number	0	+2	-1	+4

(a) Identify the oxidising agent in this reaction. Explain your reasoning with reference to oxidation numbers.[1]

21. Chlorine can be prepared using the following reaction.



(i) Explain why MnO₂(s) is described as an oxidising agent in this reaction.
Refer to oxidation numbers in your answer. [1]

(ii) State what you would observe during this reaction. [1]

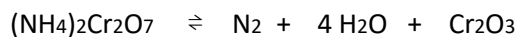
22. Bi₂O₃ can be used to form NaBiO₃, as shown in equation 1.
equation 1 $\text{Na}_2\text{O} + \text{Bi}_2\text{O}_3 + \text{O}_2 \rightarrow 2\text{NaBiO}_3$

(i) Deduce the oxidation number of Bi in Bi₂O₃ and in NaBiO₃.
oxidation number of Bi:

in Bi₂O₃ in NaBiO₃ [1]

(ii) Identify the reducing agent in equation 1. [1]

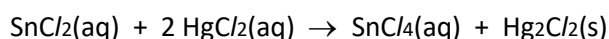
16. $(\text{NH}_4)_2\text{Cr}_2\text{O}_7$ decomposes when heated.



Which element is oxidised and which element is reduced?

	oxidised	reduced
A	chromium	nitrogen
B	hydrogen	chromium
C	nitrogen	chromium
D	nitrogen	hydrogen

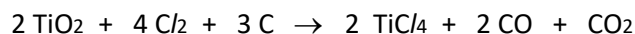
17. The equation for a redox reaction is shown.



Which species is being oxidised in this reaction?

- A** Sn^{2+} **B** Cl^- **C** Hg^+ **D** Hg^{2+}

18. The first stage in the chloride process for the manufacture of titanium consists of the following reaction.



What is reduced in this reaction?

- A** carbon **B** chlorine **C** oxygen **D** titanium

19. VO_2Cl reacts with NaI under acidic conditions.



The oxidation state of Cl is -1 in VO_2Cl and in VOCl_2 .

Which row about this reaction is correct?

	vanadium	iodine
A	is oxidised	is oxidised
B	is oxidised	is reduced
C	is reduced	is oxidised
D	is reduced	is reduced

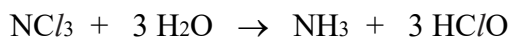
20. Silicon reacts with a mixture of calcium oxide and magnesium oxide at 1200°C .



Which statement about this reaction is correct?

- A** Calcium is reduced and silicon is neither oxidised nor reduced.
B Magnesium is reduced and calcium is neither oxidised nor reduced.
C Magnesium is reduced and silicon is neither oxidised nor reduced.
D Silicon is reduced and calcium is neither oxidised nor reduced.

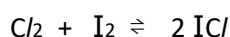
21. NCl_3 reacts with H_2O .



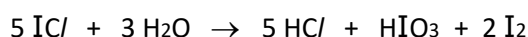
The oxidation state of nitrogen does not change in this reaction.
Which statement is correct?

- A Chlorine is reduced.
- B Chlorine is oxidised.
- C Hydrogen is both oxidised and reduced.
- D This is not a redox reaction.

22. ICl is made when Cl_2 and I_2 react together.



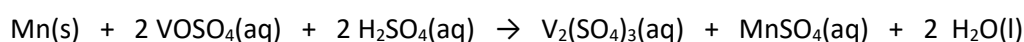
ICl reacts with water.



Which row is correct?

	oxidation number of I in ICl	reaction occurring when ICl reacts with H_2O
A	+1	the iodine atoms are oxidised to form I_2
B	+1	the iodine atoms are oxidised to form HIO_3
C	-1	the chlorine atoms are reduced to form HCl
D	-1	the iodine atoms are oxidised to form HIO_3

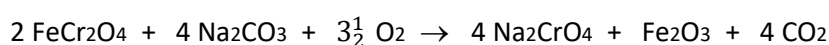
23. The vanadium salt, VOSO_4 , is soluble in water and reacts readily with powdered manganese in dilute sulfuric acid.
The equation for the reaction is shown.



Which statement about this reaction is correct?

- A Hydrogen is oxidised in the reaction.
- B Manganese is the reducing agent in this reaction.
- C Sulfuric acid is the oxidising agent in this reaction.
- D The oxidation state of the vanadium changes from +5 to +3.

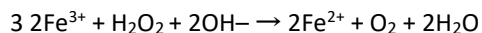
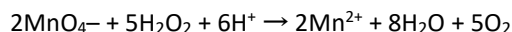
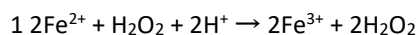
24. Sodium chromate(VI), Na_2CrO_4 , is manufactured by heating chromite, FeCr_2O_4 , with sodium carbonate in an oxidising atmosphere. Chromite contains $\text{Cr}_2\text{O}_4^{2-}$ ions.



What happens in this reaction?

- A Chromium and iron are the only elements oxidised.
- B Chromium, iron and carbon are oxidised.
- C Only chromium is oxidised.
- D Only iron is oxidised.

25. Equations for some reactions of hydrogen peroxide are given.



In which reactions is hydrogen peroxide acting as a reducing agent?

A 1 and 3

B 1 only

C 2 and 3

D 2 only

26. A student reacts 4 mol of ammonia with oxygen to produce an oxide of nitrogen and water only.

Each nitrogen atom increases its oxidation state by 5 in the reaction.

How many moles of oxygen gas react with 4 mol of ammonia in this reaction?

A 4 mol

B 5 mol

C 7 mol

D 10 mol

23. Iodine is made by reacting bromine with sodium iodide.

(i) Construct an ionic equation for the reaction of bromine with sodium iodide.

[1]

(ii) State the role of bromine in the reaction. Explain your answer.

[1]

27. The electronic arrangement for atoms of four elements is given.

Which element is the strongest oxidising agent?

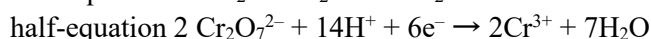
A $1s^2 2s^2 2p^5$

B $1s^2 2s^2 2p^6 3s^2$

C $1s^2 2s^2 2p^6 3s^2 3p^5$

D $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2$

24. Acidified dichromate(VI) ions will convert methanal, CH_2O , to carbon dioxide. The movement of electrons to or from relevant species is shown in the following half-equations.



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

..... [1]

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

Calculate the oxidation state of carbon in carbon dioxide.

..... [1]

(iii) Construct the ionic equation for the reaction of dichromate(VI) ions with methanal in acidic conditions.

..... [2]

Disproportionation reactions

Disproportionation can be thought of as a 'self-reduction / oxidation' reaction.

28. One of the reactions in the rechargeable lead /acid battery is shown.



Which statement about this reaction is correct?

- A Lead is both oxidised and reduced.
- B Lead is neither oxidised nor reduced.
- C Lead is oxidised only.
- D Lead is reduced only.

29. When concentrated sulfuric acid reacts with sodium iodide the products include sulfur, iodine, hydrogen sulfide and sulfur dioxide.

Which statement is correct?

- A Hydrogen sulfide is the product of a reduction reaction.
- B Iodide ions are stronger oxidising agents than sulfate ions.
- C Sulfur atoms from the sulfuric acid are both oxidised and reduced.
- D Sulfur atoms from the sulfuric acid are oxidised to make sulfur dioxide.

30. Chlorine dioxide, ClO_2 , reacts with sodium hydroxide in the reaction shown.



Which statement correctly describes this redox reaction?

- A Chlorine atoms are oxidised and oxygen atoms are reduced.
- B Chlorine atoms are reduced and oxygen atoms are oxidised.
- C Some chlorine atoms are oxidised and some chlorine atoms are reduced.
- D Some oxygen atoms are oxidised and some oxygen atoms are reduced.

31. HOCl(aq) is the molecule that kills bacteria when chlorine is added to water.
The following reaction produces this molecule.



Which statement about this reaction is correct?

- A Chlorine is both oxidised and reduced.
- B Chlorine is oxidised but **not** reduced.
- C Hydrogen is both oxidised and reduced.
- D Hydrogen is oxidised but **not** reduced.

25. In the boxes, give the oxidation numbers of nitrogen in the nitrogen-containing species for the reaction in stage 3.



[2]

- (ii) Explain why the reaction in stage 3 is described as a disproportionation reaction.
Include reference to transfer of electrons in your answer.

[2]

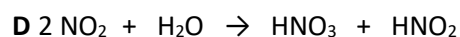
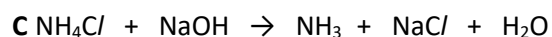
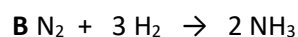
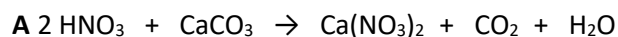
26. When KClO_3 is heated without a catalyst, KClO_4 and KCl form.



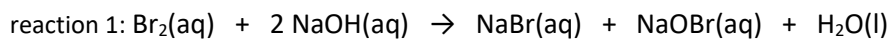
Explain why this reaction is described as a disproportionation reaction.

[1]

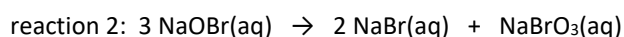
32. Four equations representing reactions of nitrogen or one of its compounds are given.
Which equation represents a disproportionation reaction?



33. Bromine reacts with aqueous sodium hydroxide at 25°C .



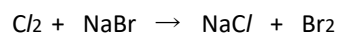
The NaOBr formed is unstable at 25°C and reacts further.



Which reactions are disproportionations?

- A both reaction 1 and reaction 2
- B neither reaction 1 nor reaction 2
- C reaction 1 only
- D reaction 2 only

34. Chlorine reacts with sodium bromide.



Which words correctly describe this reaction?

- 1 redox
- 2 displacement
- 3 disproportionation

- A 1, 2 and 3 B 1 and 2 only C 1 only D 2 only

35. Electronegativity differences can be used to help determine the oxidation number of an atom in different species. A number of rules are used which include:
- The more electronegative atom is given a negative oxidation number.
 - Hydrogen is more electronegative than Group1 metals.
 - Oxygen is more electronegative than hydrogen.
- Which row is correct?

	equation of reaction	redox reaction	disproportionation reaction
A	$2\text{CrO}_4^{2-} + 2\text{H}^+ \rightarrow \text{Cr}_2\text{O}_7^{2-} + \text{H}_2\text{O}$	✓	✗
B	$\text{NaH} + \text{H}_2\text{O} \rightarrow \text{NaOH} + \text{H}_2$	✓	✓
C	$3\text{MnO}_4^{2-} + 4\text{H}^+ \rightarrow \text{MnO}_2 + 2\text{MnO}_4^-$	✓	✓
D	$\text{VO}_3^- + 2\text{H}^+ \rightarrow \text{VO}_2^+ + \text{H}_2\text{O}$	✓	✗

36. The equation for a reaction of KClO_3 is shown.



Which row is correct?

	Disproportionation reaction	oxidation number of chlorine in KClO_4
A	yes	+4
B	yes	+7
C	no	+4
D	no	+7

The reaction of chlorine with cold and with hot aqueous sodium hydroxide

Cold (15°C)

When chlorine gas is passed into cold, dilute aqueous sodium hydroxide, the following reaction takes place and two salts are formed



Hot (70°C)



27. Bleach is made by reacting Cl_2 with cold $\text{NaOH}(\text{aq})$.
Write an equation for the reaction of Cl_2 with cold NaOH .

28. Cl_2 reacts with aqueous sodium hydroxide in a disproportionation reaction.
Write an equation for the reaction of Cl_2 with cold aqueous sodium hydroxide.

[1]

29. When Cl_2 reacts with cold $\text{NaOH}(\text{aq})$, Cl_2 is both oxidised and reduced. The products are NaCl , water and G.
(i) State the type of redox reaction in which the same species is both oxidised and reduced.

[1]

(ii) Identify G.

[1]

(iii) Write an equation for the reaction between Cl_2 and hot $\text{NaOH}(\text{aq})$.

[1]

37. Hot aqueous sodium hydroxide reacts with chlorine.



Which statement is correct?

A The oxidation numbers of chlorine and hydrogen both change in the reaction.

B The oxidation numbers of chlorine in the products are -1 and $+1$.

C If the aqueous sodium hydroxide is cold the reaction produces NaClO instead of NaClO_3 .

D Sodium undergoes disproportionation in this reaction.

30. (i) State the reagent and conditions required for the formation of sodium chlorate(V) from $\text{Cl}_2(\text{g})$.

[1]

(ii) Explain why the reaction in (i) is described as a disproportionation reaction.

Your answer should refer to relevant species and their oxidation numbers.

[1]

31. Chlorine undergoes disproportionation during many chemical reactions.

(i) Write an equation for the reaction of chlorine with cold aqueous sodium hydroxide, NaOH .

Explain why it is a disproportionation reaction.

equation

Explanation

.....
.....
..... [2]

(ii) One of the products of the reaction of chlorine with hot aqueous sodium hydroxide differs from those in (i). Identify the compound that is formed in this reaction that is different from that formed in the reaction in (i). [1]

38. Chlorine gas is reacted with cold aqueous sodium hydroxide.

Which statement is correct for this reaction?

A Chlorine is both oxidised and reduced.

B Chlorine is neither oxidised nor reduced.

C Chlorine is oxidised but not reduced.

D Chlorine is reduced but not oxidised.

39. Chlorine reacts with aqueous sodium hydroxide forming two chlorine-containing products.
Which row shows the oxidation states of chlorine in the products under the conditions stated?

	conditions	oxidation state of Cl in products
A	cold NaOH(aq)	-1 and +3
B	cold NaOH(aq)	-1 and +5
C	hot NaOH(aq)	-1 and +3
D	hot NaOH(aq)	-1 and +5

40. Z is a compound of sodium, chlorine and oxygen.
It contains 45.1% by mass of oxygen.
Z is prepared by reacting sodium hydroxide with chlorine.
Which row shows the conditions used for the reaction and the oxidation state of chlorine in Z?

	reaction conditions	oxidation state of Cl in Z
A	cold dilute NaOH	+1
B	cold dilute NaOH	+5
C	hot concentrated NaOH	+1
D	hot concentrated NaOH	+5

41. A solution of sodium hydroxide reacts with 3 mol of chlorine under certain conditions. The reaction produces 5 mol of sodium chloride and 1 mol of X, the only other chlorine-containing product.
What is the formula of compound X?

A NaClO B NaClO₂ C NaClO₃ D NaClO₄

42. An excess of chlorine was bubbled into 100 cm³ of hot 6.0 mol dm⁻³ sodium hydroxide.
How many moles of sodium chloride would be produced in the reaction?

A 0.30 B 0.50 C 0.60 D 0.72

43. NH₄NO₃ decomposes into N₂O and H₂O on heating.
Which statements are correct?

- 1 The ammonium ion is behaving as a reducing agent.
- 2 The nitrate(V) ion is behaving as an oxidising agent.
- 3 It is a redox reaction.
- 4 It is a disproportionation reaction.

A 1, 2, 3 and 4
B 1, 2 and 3 only
C 3 and 4 only
D 3 only

44. The name 'chlorate' is used for an anion consisting of chlorine and oxygen only.
In a molecule of ICl₃, the iodine atom has oxidation number x and the chlorine atom has oxidation number y.
When ICl₃ is added to H₂O, iodine is reduced.
 $4\text{ICl}_3 + 2\text{H}_2\text{O} \rightarrow 4\text{HCl} + \text{O}_2 + 2\text{I}_2$
Which statement about the value of x or y is correct?

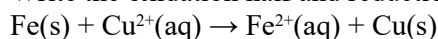
A x is the same as the oxidation number of Cl in the chlorate ion formed when Cl₂(aq) is added to cold NaOH(aq).
B x is the same as the oxidation number of Cl in the chlorate ion formed when Cl₂(aq) is added to hot NaOH(aq).
C y is the same as the oxidation number of Cl in the chlorate ion formed when Cl₂(aq) is added to cold NaOH(aq).
D y is the same as the oxidation number of Cl in the chlorate ion formed when Cl₂(aq) is added to hot NaOH(aq).

45. Sodium chlorate(I), NaClO, oxidises dilute hydrochloric acid to form three products. The products which contain chlorine have chlorine species with oxidation number -1 or 0 .
No other species changes its oxidation number during the reaction.
Use this information to complete the ionic equation.

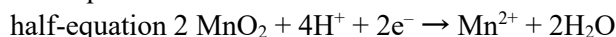
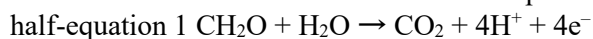


Half-equations

32. Write the oxidation half and reduction half reactions for the following equation.



33. 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.



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

.....
..... [1]

- (ii) The oxidation state of carbon in methanal is 0 .
Calculate the oxidation state of carbon in carbon dioxide.

..... [1]

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

..... [2]

Balancing redox reactions

In a redox reaction, **the number of electrons lost = the number of electrons gained**.

Remember the steps in constructing equations using oxidation numbers:

- identify oxidation number changes
- balance oxidation number changes
- balance charges
- balance atoms

46. Zinc atoms can be oxidised to Zn^{2+} ions by dichromate(VI) ions in acid solution. Chromium is reduced to Cr^{3+} in this reaction.

Which equation is correct?

- A** $\text{Cr}_2\text{O}_7^{2-} + \text{Zn} + 14\text{H}^+ \rightarrow 2\text{Cr}^{3+} + \text{Zn}^{2+} + 7\text{H}_2\text{O}$
B $\text{Cr}_2\text{O}_7^{2-} + \text{Zn} + 14\text{H}^+ \rightarrow 2\text{Cr}^{3+} + 3\text{Zn}^{2+} + 7\text{H}_2\text{O}$
C $\text{Cr}_2\text{O}_7^{2-} + 3\text{Zn} + 14\text{H}^+ \rightarrow 2\text{Cr}^{3+} + 3\text{Zn}^{2+} + 7\text{H}_2\text{O}$
D $2\text{Cr}_2\text{O}_7^{2-} + 3\text{Zn} + 14\text{H}^+ \rightarrow 2\text{Cr}^{3+} + 3\text{Zn}^{2+} + 7\text{H}_2\text{O}$

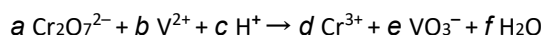
47. When the equation is correctly balanced, what is the value of c ?



- A** 3 **B** 4 **C** 5 **D** 6

48. In this question you should use changes in oxidation numbers to balance a chemical equation.

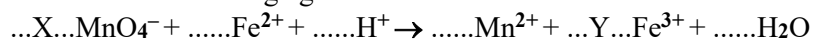
Acidified potassium dichromate(VI) solution can oxidise a solution of V^{2+} ions. The equation for this reaction is shown.



What is the ratio $a : b$ in the correctly balanced equation?

- A** 1 : 1 **B** 1 : 2 **C** 2 : 1 **D** 4 : 1

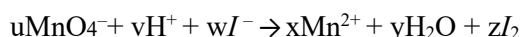
49. KMnO_4 is an oxidising agent. Its reaction with Fe^{2+} is shown in the following ionic equation.



What are X and Y when the equation is balanced?

	X	Y
A	1	1
B	1	3
C	1	5
D	5	1

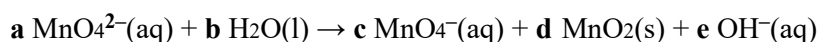
50. The ionic equation shows iodide ions reacting with manganate(VII) ions in acidic solution.



The letters u , v , w , x , y and z all represent whole numbers. Two or more of u , v , w , x , y and z are the same as each other. What is the lowest possible value of v ?

- A** 2 **B** 8 **C** 10 **D** 16

51. When K_2MnO_4 is dissolved in water, the following reaction occurs.

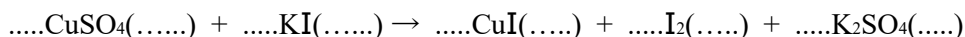


What could be the values of a and c in the balanced chemical equation?

	a	c
A	2	1
B	3	1
C	3	2
D	4	3

34. The equation shown in (i) describes the reaction which occurs when aqueous potassium iodide is added to aqueous copper(II) sulfate. A white precipitate of copper(I) iodide forms in a brown solution of iodine and potassium sulfate.

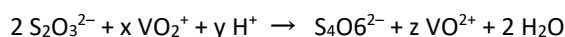
(i) Balance the equation and include state symbols.



52. Sodium dichromate (VI), $\text{Na}_2\text{Cr}_2\text{O}_7$, reacts with hydrogen peroxide, H_2O_2 , producing Cr^{3+} ions, water and oxygen. What is the correctly balanced ionic equation for this reaction?

- A $\text{Cr}_2\text{O}_7^{2-} + 2\text{H}^+ + \text{H}_2\text{O}_2 \rightarrow 2\text{Cr}^{3+} + 2\text{H}_2\text{O} + 4\text{O}_2$
 B $\text{Cr}_2\text{O}_7^{2-} + 8\text{H}^+ + 3\text{H}_2\text{O}_2 \rightarrow 2\text{Cr}^{3+} + 7\text{H}_2\text{O} + 3\text{O}_2$
 C $\text{Cr}_2\text{O}_7^{2-} + 8\text{H}^+ + 6\text{H}_2\text{O}_2 \rightarrow 2\text{Cr}^{3+} + 10\text{H}_2\text{O} + 6\text{O}_2$
 D $\text{Cr}_2\text{O}_7^{2-} + 14\text{H}^+ + 3\text{H}_2\text{O}_2 \rightarrow 2\text{Cr}^{3+} + 7\text{H}_2\text{O} + 3\text{O}_2$

53. The equation for the reaction of aqueous thiosulfate ions, $\text{S}_2\text{O}_3^{2-}$, and aqueous dioxo-vanadium ions, VO_2^+ , is shown.



Which row shows two correct statements about the equation for this reaction?

	comparison of x and y to z	change in oxidation number of vanadium
A	x and z are the same value and quarter the value of y	from +4 to +5
B	x and z are the same value and quarter the value of y	from +5 to +4
C	x and z are the same value and half the value of y	from +5 to +4
D	x and z are the same value and half the value of y	from +4 to +5

54. Chlorine is bubbled through 100 cm³ of hot 4.0 mol dm⁻³ sodium hydroxide until the reaction is complete.



Which row is correct?

	x	[Na ⁺](aq) after reaction / mol dm ⁻³
A	3	4.0
B	3	less than 4.0
C	6	4.0
D	6	less than 4.0

55. Oxygen can be prepared by the reaction of potassium manganate(VII), KMnO_4 , hydrogen peroxide, H_2O_2 , and sulfuric acid, H_2SO_4 . Each H_2O_2 molecule loses two electrons in this reaction. The other products of the reaction are potassium sulfate, manganese(II) sulfate and water.

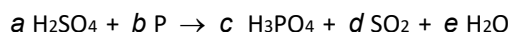
How many moles of oxygen gas are produced when 1.0 mol of KMnO_4 reacts with an excess of H_2O_2 in acidic conditions?

- A 2.0 mol B 2.5 mol C 4.5 mol D 5.0 mol

56. Two moles of VO_2^+ ions react with one mole of zinc atoms in the presence of dilute acid. The products include Zn^{2+} ions and an ion, Y. Ion Y contains vanadium. Only zinc and vanadium change oxidation state in the reaction. What is ion Y?

- A VO_3^- B VO^+ C VO^{2+} D VO_2^{2+}

57. Phosphorus reacts with concentrated sulfuric acid to produce phosphoric acid, sulfur dioxide and water.



a , b , c , d and e are all whole numbers.

The equation can be balanced by using oxidation numbers.

What is the value of the sum $a + b + c + d + e$?

A 10

B 14

C 15

D 16

58. Copper dissolves in dilute nitric acid producing a blue solution of $\text{Cu}(\text{NO}_3)_2$, water and nitrogen(II) oxide as the only products.

How many moles of acid react with three moles of copper in the balanced equation?

A 2

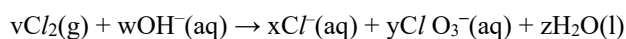
B 4

C 6

D 8

59. Chlorate(V) ions, ClO_3^- , are produced in the redox reaction between chlorine and hot aqueous sodium hydroxide.

Oxidation numbers can be used to help balance the equation for this reaction.



What are the values of v , x and y in the balanced equation?

	v	x	y
A	2	3	1
B	3	4	2
C	3	5	1
D	7	12	2

60. ICl_3 reacts with water in a redox reaction.



What are the numbers v , x and z in the correctly balanced equation?

	v	x	z
A	2	8	1
B	2	5	1
C	3	8	1
D	3	5	1

61. W moles of HNO_2 undergoes a disproportionation reaction to produce U moles of HNO_3 and V moles of NO .

- No other nitrogen containing product is produced.
- Nitrogen is the only element oxidised or reduced.

What are the values of W , U and V ?

	W	U	V
A	2	1	1
B	3	1	2
C	5	3	2
D	5	1	4

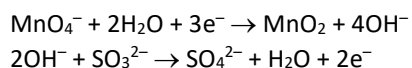
62. In alkaline solution, MnO_4^- ions oxidise SO_3^{2-} ions to SO_4^{2-} ions. The MnO_4^- ions are reduced to MnO_2 . What is the ratio of the two ions in the balanced chemical equation for this reaction?

	MnO_4^-	SO_3^{2-}
A	2	3
B	3	2
C	4	7
D	7	4

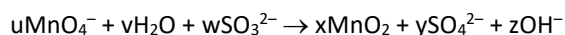
63. The ore psilomelane may be considered to have the general formula $\text{Ba}(\text{Mn}_{x+})(\text{Mn}_{y+})_8\text{O}_{16}(\text{OH})_4$. In this general formula, $x+$ and $y+$ are the two different oxidation states of manganese in psilomelane. What could be the values of x and y ?

	x	y
A	2	4
B	6	4
C	6	3
D	7	3

64. Two half-equations are shown.



The equation for the reaction between manganate(VII) ions and sulfite ions is shown.

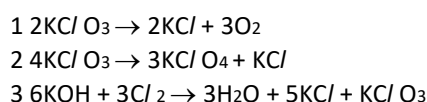


Which statements are correct?

- $u = x = z$
- Manganese is reduced to oxidation state + 4.
- Sulfur is oxidised from oxidation state + 4 to + 6.

A 1, 2 and 3 **B** 1 and 2 only **C** 1 and 3 only **D** 2 and 3 only

65. The equations for three reactions involving chlorine or its compounds are listed.



Which statement about these equations is correct?

- A** Equation 1 describes the formation of a compound used to kill bacteria in drinking water.
B Equation 1 does **not** represent a redox reaction.
C Equation 2 describes the formation of potassium chlorate(IV).
D Equations 2 and 3 both represent disproportionation reactions.

66. Copper reacts with nitric acid under certain conditions. The products are copper(II) nitrate, water and an oxide of nitrogen.

3 mol of copper reacts with exactly 8 mol of nitric acid.

What is the oxidation state of nitrogen in the oxide produced?

A +1 **B** +2 **C** +3 **D** +4

35. Table 1.2 shows the melting points of some oxides.

Table 1.2

Oxide	melting point / °C
SO ₂	-73
H ₂ O	0
SO ₃	17
SiO ₂	1610
MgO	2852
Al ₂ O ₃	2072

A student suggests the following hypothesis.

The higher the oxidation number of the element combined with oxygen, the higher the melting point of the oxide.

Use Table 1.2 to deduce if this hypothesis is true or false, or if there is not enough information to make a conclusion. Explain your answer.

.....
.....
..... [2]

67. A student adds 3 mol of acidified K₂Cr₂O₇ to an excess of I⁻ ions.
The chromium is all reduced to Cr³⁺ and I⁻ ions are oxidised to I₂.
The I₂ released is reduced back to I⁻ ions by X mol of S₂O₃²⁻ ions.
1 mol of I₂ is reduced by 2 mol of S₂O₃²⁻ ions.
What is the value of X?

A 3 B 6 C 9 D 18

***This is not a complete note. It is just to guide you. It is recommended to study prescribed textbooks along with this material. ***