6. Electrochemistry

6.1 Redox processes

Paper 1

Question Paper

1 Equations for some reactions of hydrogen peroxide are given.

1 $2Fe^{2+} + H_2O_2 + 2H^+ \rightarrow 2Fe^{3+} + 2H_2O$

2 $2MnO_4^- + 5H_2O_2 + 6H^+ \rightarrow 2Mn^{2+} + 8H_2O + 5O_2$

3 $2Fe^{3+} + H_2O_2 + 2OH^- \rightarrow 2Fe^{2+} + O_2 + 2H_2O$

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

2 The equation for the reaction of aqueous thiosulfate ions, $S_2O_3^{2-}$, and aqueous dioxo-vanadium ions, VO_2^+, is shown.

$$2S_2O_3^{2-} + xVO_2^+ + yH^+ \rightarrow S_4O_6^{2-} + zVO^{2+} + 2H_2O$$

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

3 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

4 Sodium chromate(VI), Na_2CrO_4, is manufactured by heating chromite, $FeCr_2O_4$, with sodium carbonate in an oxidising atmosphere. Chromite contains $Cr_2O_4^{2-}$ ions.

$$2FeCr_2O_4 + 4Na_2CO_3 + 3\tfrac{1}{2}O_2 \rightarrow 4Na_2CrO_4 + Fe_2O_3 + 4CO_2$$

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.

5 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

6 Nitrogen dioxide reacts with water.

$$2NO_2 + H_2O \rightarrow HNO_2 + HNO_3$$

Which statement about this reaction is correct?

A Both products are formed because oxygen atoms gain electrons.

B Nitrogen atoms undergo disproportionation.

C The oxidation number of hydrogen is increased.

D Water acts as an oxidising agent.

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

$$aH_2SO_4 + bP \rightarrow cH_3PO_4 + dSO_2 + eH_2O$$

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

8 Zinc reacts with concentrated nitric acid giving three products only: zinc nitrate, an oxide of nitrogen and water.

3.0 moles of zinc react with 8.0 moles of nitric acid. Zinc nitrate contains Zn^{2+} ions.

What could be the formula of the oxide of nitrogen?

A N_2O **B** NO **C** N_2O_3 **D** NO_2

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

$$2Cu^{2+}(aq) + 4I^{-}(aq) \rightarrow 2CuI(s) + I_2(aq)$$

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

10 $LiAlH_4$ contains AlH_4^{-} ions in which aluminium has an oxidation state of +3.

$LiAlH_4$ reacts with water, as shown.

$$LiAlH_4 + 4H_2O \rightarrow 4H_2 + LiOH + Al(OH)_3$$

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.

11 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.

$$Mn(s) + 2VOSO_4(aq) + 2H_2SO_4(aq) \rightarrow V_2(SO_4)_3(aq) + MnSO_4(aq) + 2H_2O(l)$$

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.

12 Ammonium ions are converted into nitrate ions by bacteria.

What is the change in the oxidation number of nitrogen?

A –6 **B** +6 **C** +8 **D** +9

13 Sodium dichromate(VI), $Na_2Cr_2O_7$, 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 $Cr_2O_7^{2-} + 2H^+ + H_2O_2 \rightarrow 2Cr^{3+} + 2H_2O + 4O_2$

B $Cr_2O_7^{2-} + 8H^+ + 3H_2O_2 \rightarrow 2Cr^{3+} + 7H_2O + 3O_2$

C $Cr_2O_7^{2-} + 8H^+ + 6H_2O_2 \rightarrow 2Cr^{3+} + 10H_2O + 6O_2$

D $Cr_2O_7^{2-} + 14H^+ + 3H_2O_2 \rightarrow 2Cr^{3+} + 7H_2O + 3O_2$

14 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+}

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.

16 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

17 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

18 NCl_3 reacts with H_2O.

$$NCl_3 + 3H_2O \rightarrow NH_3 + 3HClO$$

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.

19 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+}

20 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 $Cr_2O_7^{2-} + Zn + 14H^+ \rightarrow 2Cr^{3+} + Zn^{2+} + 7H_2O$

B $Cr_2O_7^{2-} + Zn + 14H^+ \rightarrow 2Cr^{3+} + 3Zn^{2+} + 7H_2O$

C $Cr_2O_7^{2-} + 3Zn + 14H^+ \rightarrow 2Cr^{3+} + 3Zn^{2+} + 7H_2O$

D $2Cr_2O_7^{2-} + 3Zn + 14H^+ \rightarrow 2Cr^{3+} + 3Zn^{2+} + 7H_2O$

21 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

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

$$8HI + H_2SO_4 \rightarrow H_2S + 4H_2O + 4I_2$$

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

23 The equation for a redox reaction is shown.

$$SnCl_2(aq) + 2HgCl_2(aq) \rightarrow SnCl_4(aq) + Hg_2Cl_2(s)$$

Which species is being oxidised in this reaction?

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

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

A $S(s) + O_2(g) \rightarrow SO_2(g)$

B $SO_2(g) + \frac{1}{2}O_2(g) \rightleftharpoons SO_3(g)$

C $SO_3(g) + H_2SO_4(l) \rightarrow H_2S_2O_7(l)$

D $H_2S_2O_7(l) + H_2O(l) \rightarrow 2H_2SO_4(l)$

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

$$2TiO_2 + 4Cl_2 + 3C \rightarrow 2TiCl_4 + 2CO + CO_2$$

What is reduced in this reaction?

A carbon

B chlorine

C oxygen

D titanium

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

	$Ca(HSO_3)_2$	$Na_2S_2O_3$
A	4	2
B	4	4
C	6	2
D	6	4

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

$$2ClO_2 + 2OH^- \rightarrow ClO_2^- + ClO_3^- + H_2O$$

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.

28 What is the oxidation number of sulfur in each species?

	H_2S	SO_2	H_2SO_3
A	–2	+4	+4
B	–2	+4	+6
C	+2	–4	+4
D	+2	–4	+6

29 In the chemical equation, w, x, y and z are all whole numbers.

$$wClO_3^- + xMnO_4^- + yH^+ \rightarrow wClO_4^- + xMnO_2 + zH_2O$$

When the equation is balanced, what are w, x and y?

	w	x	y
A	1	1	2
B	2	2	2
C	2	3	8
D	3	2	2

30 $(NH_4)_2Cr_2O_7$ decomposes when heated.

$$(NH_4)_2Cr_2O_7 \rightarrow N_2 + 4H_2O + Cr_2O_3$$

Which element is oxidised and which element is reduced?

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

31 When lead(II) sulfide, PbS, is heated in air, sulfur dioxide and lead(II) oxide are formed.

What is the equation for the reaction between PbS and oxygen?

A $PbS + 2O_2 \rightarrow SO_2 + PbO_2$

B $PbS + 2\frac{1}{2}O_2 \rightarrow SO_3 + PbO_2$

C $PbS + 1\frac{1}{2}O_2 \rightarrow SO_2 + PbO$

D $PbS + 2O_2 \rightarrow SO_3 + PbO$

32 Ethanedioic acid, HO_2CCO_2H, can be oxidised by $KMnO_4$ in dilute sulfuric acid. The products of this reaction are carbon dioxide, water, potassium sulfate and manganese(II) sulfate.

In this reaction each ethanedioic acid molecule loses two electrons as it is oxidised. A half-equation for this process is shown.

$$HO_2CCO_2H \rightarrow 2CO_2 + 2H^+ + 2e^-$$

How many water molecules are produced when five ethanedioic acid molecules are oxidised by $KMnO_4$ in dilute sulfuric acid?

A 5 **B** 8 **C** 10 **D** 16

33 Nitric acid is known to take part in the oxidation of atmospheric sulfur dioxide. One possible reaction is shown.

$$SO_2 + HNO_3 \rightarrow NO^+ + HSO_4^-$$

Which row shows the correct changes in oxidation numbers of nitrogen and sulfur?

	nitrogen	sulfur
A	–3	+3
B	–2	+2
C	–2	+3
D	–1	+2

34 A transition metal ion, M^{2+}, reacts with acidified dichromate(VI) ions to form M^{4+} ions, Cr^{3+} ions, and H_2O.

Which equation correctly represents this reaction?

A $Cr_2O_7^{2-} + 14H^+ + M^{2+} \rightarrow 2Cr^{3+} + 7H_2O + M^{4+}$

B $Cr_2O_7^{2-} + 14H^+ + 2M^{2+} \rightarrow 2Cr^{3+} + 7H_2O + 2M^{4+}$

C $Cr_2O_7^{2-} + 14H^+ + 3M^{2+} \rightarrow 2Cr^{3+} + 7H_2O + 3M^{4+}$

D $Cr_2O_7^{2-} + 14H^+ + 6M^{2+} \rightarrow 2Cr^{3+} + 7H_2O + 6M^{4+}$

35 Ammonium metavanadate, NH_4VO_3, can be used to make a solution containing VO_2Cl, which contains chloride ions.

What is the **change** in the oxidation number of vanadium in this reaction?

A –1 **B** 0 **C** +1 **D** +2

36 Ethanedioate ions, $C_2O_4^{2-}$, react with a suitable reagent to form CO_2. A half-equation for this reaction is shown.

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

Which row is correct?

	oxidation state of carbon in $C_2O_4^{2-}$	type of reaction
A	+3	oxidation
B	+3	reduction
C	+5	oxidation
D	+5	reduction

37 Oxidation numbers should be used to answer this question.

A redox reaction takes place between hydroxylammonium ions, $[NH_3OH]^+$, and acidified iron(III) ions, Fe^{3+}. The products are iron(II) ions, Fe^{2+}, H^+ ions, water and a compound of nitrogen.

The mole ratio of reacting hydroxylammonium ions to reacting iron(III) ions is 1 : 2.

Which nitrogen-containing compound could be formed in the reaction?

A NH_3 **B** N_2O **C** NO **D** NO_2

38 Sulfur reacts with concentrated nitric acid in a redox reaction.

$$S + 4HNO_3 \rightarrow SO_2 + 4NO_2 + 2H_2O$$

What are the changes in oxidation number of sulfur and of nitrogen in this reaction?

	sulfur	nitrogen
A	+2	–3
B	+2	–1
C	+4	–3
D	+4	–1