

AS CHEMISTRY 9701

Crash Course

PROSPERITY ACADEMY

RUHAB IQBAL

REDOX REACTIONS

COMPLETE NOTES



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Redox Reactions:-

Oxidation:- loss of electrons or increase in oxidation number (Number of electrons an atom has gained control of or lost control of)

Reduction:- gain of electrons or decrease in oxidation number

Important Keypoints:-

- 1) Oxidation number of an element is zero(0) e.g. Na, Cl_2 , O_2 , H_2
- 2) Oxidation number of an ion is equal to charge on it e.g. +1 for Na^+ , -1 for Cl^- , -2 for O^{2-}
- 3) Group 1 elements are always +1
- 4) Group 2 elements are always +2
- 5) Group 3 elements are always +3
- 6) Fluorine is always -1.
- 7) Oxygen is always -2 unless it is combined with fluorine or is in the form of a peroxide or superoxide
- 8) Hydrogen is nearly always +1

a) Oxidation numbers of all elements in a neutral compound must add upto zero.

b) Oxidation numbers of all elements in a complex ion must add upto the charge on the ion.

ii) Important ions:- NO_3^- (nitrate), CO_3^{2-} (carbonate), SO_4^{2-} (sulphate), OH^- (hydroxide), NH_4^+ (ammonium), HCO_3^- (hydrogen carbonate), PO_4^{3-} (phosphate)

Q. Write the formulae for the following compounds:-

1) Titanium(IV) chloride
 $\text{Ti}^{4+} \text{Cl}^-$
 TiCl_4

2) Titanium(IV) oxide
 $\text{Ti}^{4+} \text{O}^{2-}$
 TiO_2

3) Vanadium(III) Bromide
 $\text{V}^{3+} \text{Br}^-$
 VBr_3

4) Vanadium(V) oxide
 $\text{V}^{5+} \text{O}^{2-}$
 V_2O_5

5) Chromium(III) oxide
 $\text{Cr}^{3+} \text{O}^{2-}$
 Cr_2O_3

6) Chromium(VI) oxide
 $\text{Cr}^{6+} \text{O}^{2-}$
 CrO_3

7) Iron(II) Sulphate
 $\text{Fe}^{2+} \text{SO}_4^{2-}$
 FeSO_4

8) Copper(I) oxide
 $\text{Cu}^+ \text{O}^{2-}$
 Cu_2O

9) Copper(II) oxide
 $\text{Cu}^{2+} \text{O}^{2-}$
 CuO

10) Iron(III) Sulphate
 $\text{Fe}^{3+} \text{SO}_4^{2-}$
 $\text{Fe}_2(\text{SO}_4)_3$

11) Sodium hydrogencarbonate
 $\text{Na}^+ \text{HCO}_3^-$
 NaHCO_3

12) Magnesium nitrate
 $\text{Mg}^{2+} \text{NO}_3^-$
 $\text{Mg}(\text{NO}_3)_2$

Q. Calculate oxidation numbers of underlined atoms:-

1) H_2O
 $2x - 2 = 0$
 $x = +1$

2) Cu_2O
 $2x - 2 = 0$
 $x = +1$

3) HNO_3
 $+1 + x + 3(-2) = 0$
 $x = +5$

4) H_2SO_4
 $+2 + x + 4(-2) = 0$
 $x = +6$

5) Cl_2O
 $2x - 2 = 0$
 $x = +1$

6) Cl_2O_7
 $+2x + 7(-2) = 0$
 $x = +7$

7) NaClO
 $+1 + x - 2 = 0$
 $x = +1$

8) KMnO_4
 $+1 + x + 4(-2) = 0$
 $x = +7$

9) $\text{K}_2\text{Cr}_2\text{O}_7$
 $2(+1) + 2x + 7(-2) = 0$
 $x = +6$

10) $\text{Na}_2\text{S}_2\text{O}_3$
 $2(+1) + 2x + 3(-2) = 0$
 $x = +2$

11) KClO_3
 $+1 + x + 3(-2) = 0$
 $x = +5$

12) Cl_2
 $x = 0$

13) MnO_4^{2-}
 $x + 4(-2) = -2$
 $x = +6$

14) $\text{Cr}_2\text{O}_7^{2-}$
 $2x + 7(-2) = -2$
 $x = +6$

15) SO_3^{2-}
 $x + 3(-2) = -2$
 $x = +4$

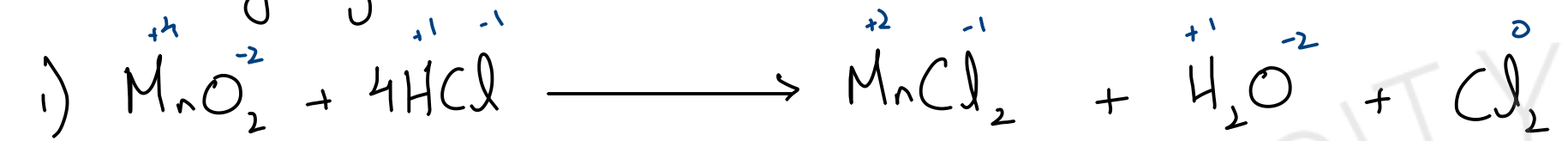
Reducing agent:- A species which reduces other species in the reaction and gets oxidised its ownself

Oxidising agent:- A species which oxidises other species in the reaction and gets reduced its ownself

Another way to identify oxidation $\longrightarrow$ Addition of oxygen / removal of hydrogen

Another way to identify reduction $\longrightarrow$ Addition of hydrogen / removal of oxygen

Q. In the following reactions, identify which species was reduced and which species was oxidised as well as the oxidising and reducing agent.

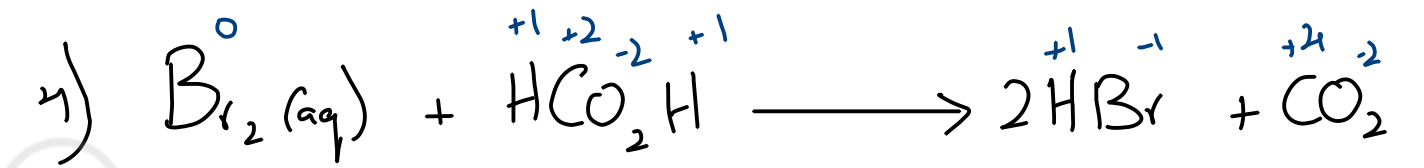


Oxidised: Cl as its oxidation number increased from -1 to 0.

Reduced: Mn as its oxidation number decreased from +4 to +2.

Oxidising agent: Mn

Reducing agent: Cl



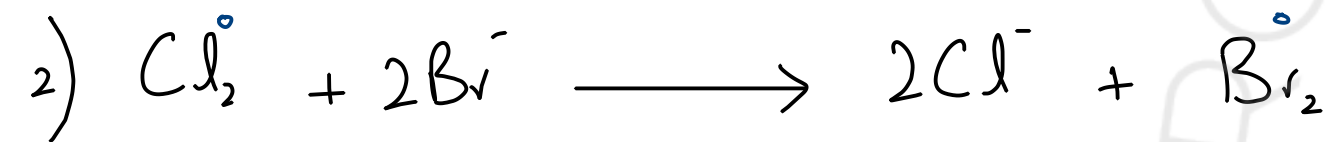
Oxidised: C as +2 $\rightarrow$ +4

Reduced: Br as 0 $\rightarrow$ -1

Oxidising agent: Br

Reducing agent: C

$$\left(\begin{array}{l} x + 1 + 1 + 2(-2) = 0 \\ x = +2 \end{array} \right)$$

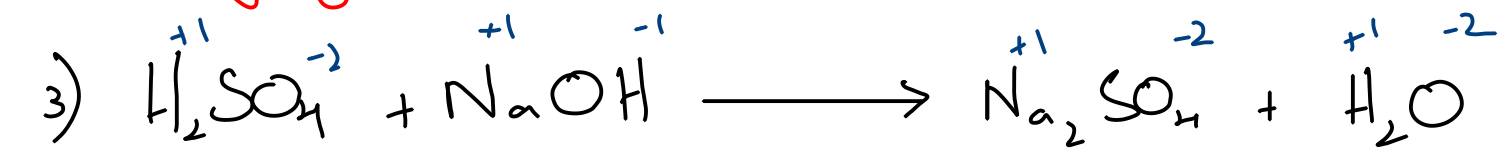


Oxidised: Br as oxidation no. -1 $\rightarrow$ 0

Reduced: Cl as oxidation no. 0 $\rightarrow$ -1

Oxidising agent: Cl

Reducing agent: Br



Oxidised: NOT A REDOX REACTION

Reduced:

Oxidising agent:

Reducing agent:

Combining half equations:-

1) Oxidation of bromide ions by chlorine molecules

Half equation for oxidation for bromide ions:- $2\text{Br}^- \longrightarrow \text{Br}_2 + 2\text{e}^-$

Half equation for reduction of chlorine molecules:- $\text{Cl}_2 + 2\text{e}^- \longrightarrow 2\text{Cl}^-$

Combined: $2\text{Br}^- + \text{Cl}_2 + \cancel{2\text{e}^-} \longrightarrow \text{Br}_2 + \cancel{2\text{e}^-} + 2\text{Cl}^-$
 $2\text{Br}^- + \text{Cl}_2 \longrightarrow \text{Br}_2 + 2\text{Cl}^-$

2) Oxidation of sodium atoms by oxygen molecules:-

Half equation for oxidation for sodium atoms :- $(\text{Na} \longrightarrow \text{Na}^+ + \text{e}^-) \times 4$

Half equation for reduction of oxygen molecules:- $\text{O}_2 + 4\text{e}^- \longrightarrow 2\text{O}^{2-}$

Combined: $4\text{Na} + \text{O}_2 + \cancel{4\text{e}^-} \longrightarrow 4\text{Na}^+ + 2\text{O}^{2-} + \cancel{4\text{e}^-}$
 $4\text{Na} + \text{O}_2 \longrightarrow 4\text{Na}^+ + 2\text{O}^{2-}$

3) Oxidation of chloride ions to chlorine by acidified manganate(VII) ions

Half equation for oxidation of chloride ions :- $(2\text{Cl}^- \longrightarrow \text{Cl}_2 + 2\text{e}^-) \times 5$

Half equation for reduction of manganate(VII) ions :- $(\text{MnO}_4^- + 8\text{H}^+ + 5\text{e}^- \longrightarrow \text{Mn}^{2+} + 4\text{H}_2\text{O}) \times 2$

$$\text{Mn in MnO}_4^- \Rightarrow 4(-2) + x = -1$$

$$x = +7$$

Mn goes from +7 to +2 $\rightarrow$ we need 5e^-

Combined: $10\text{Cl}^- + 2\text{MnO}_4^- + 16\text{H}^+ + \cancel{10\text{e}^-} \longrightarrow 5\text{Cl}_2 + \cancel{10\text{e}^-} + \text{Mn}^{2+} + 4\text{H}_2\text{O}$

$10\text{Cl}^- + 2\text{MnO}_4^- + 16\text{H}^+ \longrightarrow 5\text{Cl}_2 + \text{Mn}^{2+} + 4\text{H}_2\text{O}$

4) The disproportionation of Cu(I) ions in solution:-

Half equation for oxidation of copper ions :- $\text{Cu}^+ \longrightarrow \text{Cu}^{2+} + \text{e}^-$

Half equation for reduction of copper ions :- $\text{Cu}^+ + \text{e}^- \longrightarrow \text{Cu}$

Combined: $2\text{Cu}^+ \longrightarrow \text{Cu}^{2+} + \text{Cu}$

Disproportionation:- Simultaneous oxidation and reduction of an element.

s) Disproportionation of Chlorate (I) to chloride and chlorate (V)

Half equation for the oxidation of chlorate (I) to chlorate (V): $\text{ClO}^- + 2\text{H}_2\text{O} \longrightarrow \text{ClO}_3^- + 4\text{H}^+ + 4\text{e}^-$

$$\text{Cl in } \text{ClO}^- = x - 2 = -1$$
$$x = +1$$

$$\text{Cl in } \text{ClO}_3^- = x + 3(-2) = -1$$
$$x = +5$$

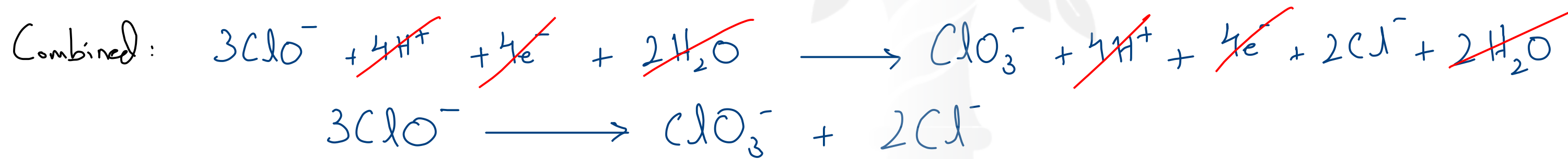
Cl goes from +1 to +5, we lose 4e^-

Half equation for the reduction of chlorate (I) to chloride: $(\text{ClO}^- + 2\text{H}^+ + 2\text{e}^- \longrightarrow \text{Cl}^- + \text{H}_2\text{O}) \times 2$

$$\text{Cl in } \text{ClO}^- = x - 2 = -1$$
$$x = +1$$

$$\text{Cl in } \text{Cl}^- = x = -1$$

Cl goes from +1 to -1, we need 2e^-



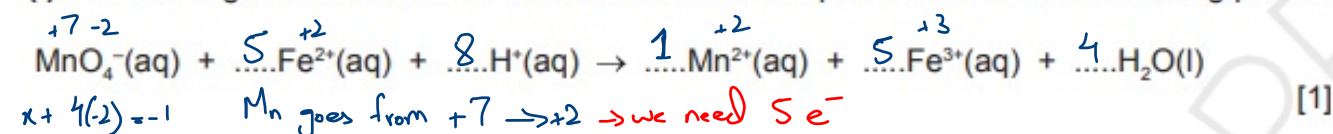
(d) Mohr's salt, $(\text{NH}_4)_2\text{Fe}(\text{SO}_4)_2 \cdot x\text{H}_2\text{O}$, is the hydrated form of ammonium iron(II) sulfate.

x represents the number of moles of water in 1 mole of the salt.

A student wanted to determine the value of x. 0.784 g of the hydrated salt was dissolved in water and this solution was acidified.

All of the solution was titrated with $0.0200 \text{ mol dm}^{-3}$ potassium manganate(VII). 20.0 cm^3 of this potassium manganate(VII) solution was required for complete reaction with the Fe^{2+} ions.

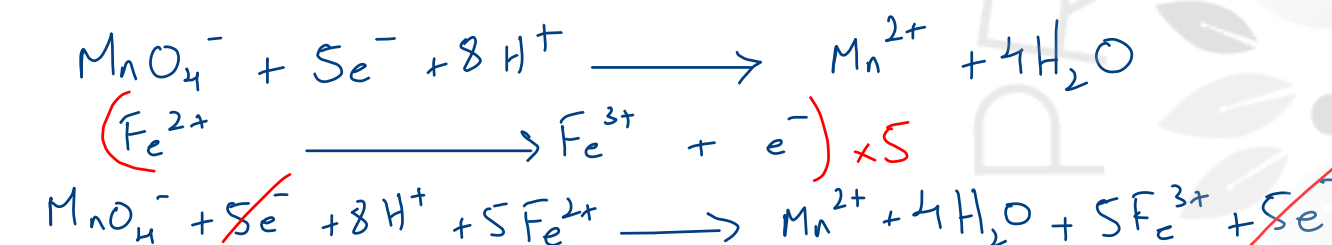
(i) Use changes in oxidation numbers to balance the equation for the reaction taking place.



(ii) State the role of the Fe^{2+} ions in this reaction.

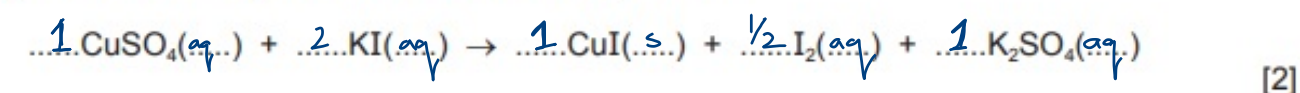
Explain your answer.

They act as reducing agent as they reduce Mn from +7 to +2 [2]



2 (a) The equation shown in (a)(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.



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

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

- oxidation number of copper in CuSO_4 +2
- oxidation number of copper in CuI +1

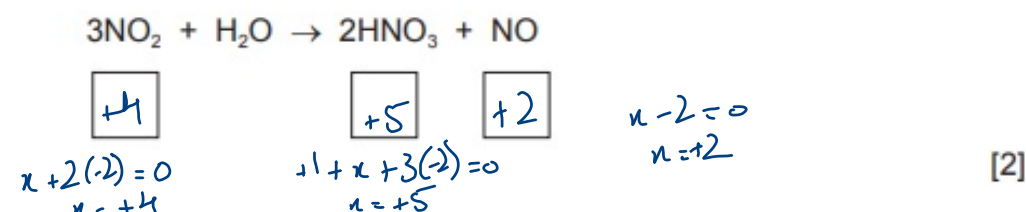
[1]

(iii) Describe the type of reaction shown by the equation in (a)(i). Explain your answer in terms of electron transfer.

Redox reaction. Cu gained an electron and went from +2 to +1.
Iodine lost an electron and went from -1 to 0.

[2]

(c) (i) In the boxes, give the oxidation numbers of nitrogen in the nitrogen-containing species for the reaction in stage 3.

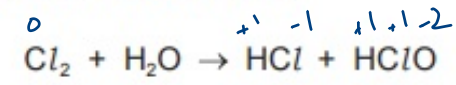


[2]

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

Because simultaneous reduction and oxidation has occurred. Nitrogen in NO_2 was oxidised from +4 to +5 in HNO_3 by losing an electron and also reduced from +4 in NO_2 to +2 in NO by gaining 2 electrons [2]

(b) $\text{Cl}_2(\text{g})$ dissolves in cold water and reacts with it.



(i) Identify the oxidation number of chlorine in each of the chlorine-containing species in this reaction.

chlorine-containing species	Cl_2	HCl	HClO
oxidation number of chlorine	0	-1	+1

[2]

(ii) Name the type of reaction occurring.

disproportionation

[1]

(iii) Explain why chlorine is used in the purification of water.

It lowers the pH of the water and kills harmful microorganisms as it forms HCl and HClO

[1]

~~(c) A mixture of HCl and HClO is added to cold dilute NaOH . One of the products behaves as a bleach.~~

~~Suggest the equation for the reaction occurring.~~

~~will learn later.~~

~~[2]~~

[Total: 13]

1 When ammonia is converted into nitric acid on a commercial scale, the following reactions can occur.

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

reaction	
A	$\overset{-3}{4}\text{NH}_3 + \overset{-2}{5}\text{O}_2 \rightarrow \overset{+2}{4}\text{NO} + \overset{-2}{6}\text{H}_2\text{O}$
B	$\overset{+1}{3}\text{NO}_2 + \text{H}_2\text{O} \rightarrow \overset{+1}{2}\text{HNO}_3 + \text{NO}$
C	$\overset{+2}{2}\text{NO} + \text{O}_2 \rightarrow \overset{+2}{2}\text{NO}_2$
D	$\overset{-3}{4}\text{NH}_3 + \overset{+2}{6}\text{NO} \rightarrow \overset{0}{5}\text{N}_2 + \overset{-2}{6}\text{H}_2\text{O}$

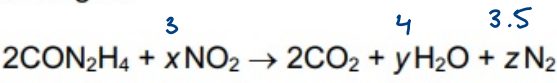
→ 5

→ 1, 2

→ 2

→ 3, 2

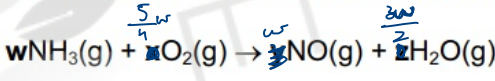
2 Granular urea, CON_2H_4 , can be used to remove NO_2 from the flue gases of power stations, converting it into harmless nitrogen.



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

	x	y	z
A	1½	2	1¼
B	2	4	3
C	3	4	3½
D	3	4	3

5 The first stage in the manufacture of nitric acid is the oxidation of ammonia by oxygen.



Which values for w, x, y and z are needed to balance the equation?

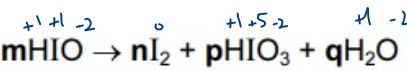
	w	x	y	z
A	4	5	4	6
B	4	6	4	5
C	5	6	5	4
D	6	5	6	4

$3w = 2z$

$z = \frac{3w}{2}$

$2x = w + \frac{3w}{2} = \frac{5}{2}w$

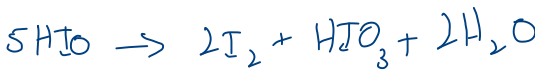
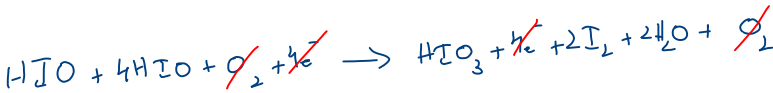
10 In aqueous solution, the acid HIO disproportionates according to the following equation where m, n, p and q are simple whole numbers in their lowest ratios.



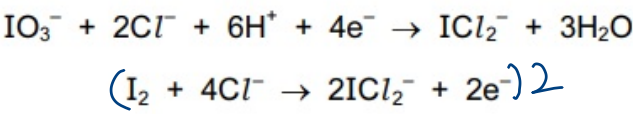
This equation can be balanced using oxidation numbers.

What are the values for n and p?

	n	p
A	1	2
B	2	1
C	4	1
D	4	2



22 The following half reactions occur when potassium iodate(V), KIO_3 , in hydrochloric acid solution oxidises iodine to ICl_2^- .

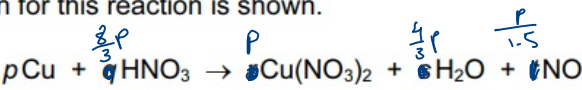


What is the ratio of IO_3^- to I_2 in the balanced chemical equation for the overall reaction?

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

36 When copper reacts with a 50% solution of nitric acid, nitrogen monoxide is evolved and a blue solution results.

The balanced equation for this reaction is shown.

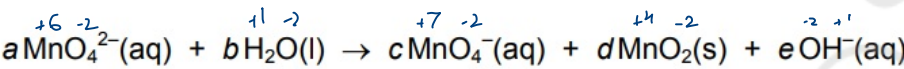


What are the values of the integers p , q , r , s and t ?

	p ✓	q ✓	r ✓	s ✓	t
A	1	4	1	2	2
B	2	6	2	3	2
C	2	8	2	4	4
D	3 ✓	8 ✓	3 ✓	4 ✓	2 ✓

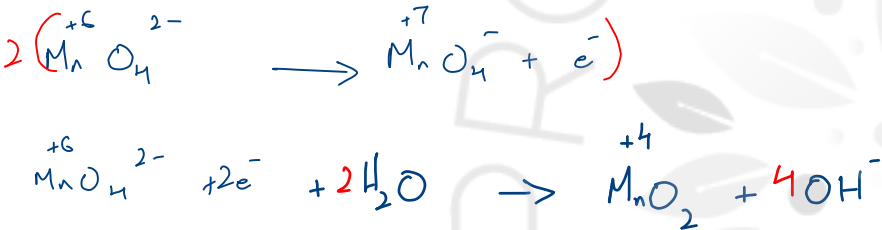
$0q = 2s$
 $\textcircled{1} q = 2p + t$
 $\textcircled{2} 3q = 6p + s + t$
 $2.5q = 6p + t$
 $5p + 2.5t = 6p + t$
 $1.5t = p \Rightarrow t = \frac{p}{1.5}$

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

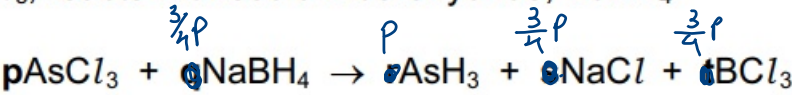


What are the values of a and c in the balanced chemical equation?

	a	c
A	2	1
B	3	2
C	4	3
D	5	4



31 Arsenic chloride, AsCl_3 , reacts with sodium borohydride, NaBH_4 .



What are the numbers p , q , r , s and t when this equation is balanced correctly?

	p	q	r	s	t
A	2	3 ✗	2	3	1
B	3	3 ✗	3	3	2
C	4 ✓	3 ✓	4 ✓	3 ✓	3 ✓
D	4	4 ✗	4	4	3

$4q = 3p$
 $q = \frac{3}{4}p$
 $3p = \frac{3}{4}p + 3t$
 $t = \frac{3}{4}p$