6 Chemical reactions

Content

6.1 Rate of reaction

6.2 Redox

6.3 Reversible reactions

Learning outcomes

Candidates should be able to:

6.1 Rate of reaction

(a) describe the effect of concentration, pressure, particle size and temperature on the rates of reactions and explain these effects in terms of collisions between reacting particles

(b) define the term *catalyst* and describe the effect of catalysts (including enzymes) on the rates of reactions

(c) explain how pathways with lower activation energies account for the increase in rates of reactions

(d) state that transition elements and their compounds act as catalysts (see 8.3) in a range of industrial processes and that enzymes are biological catalysts

(e) suggest a suitable method for investigating the effect of a given variable on the rate of a reaction

(f) interpret data obtained from experiments concerned with rate of reaction

6.2 Redox

(a) define oxidation and reduction (redox) in terms of oxygen/hydrogen gain/loss

(b) define redox in terms of electron transfer

(c) identify redox reactions in terms of oxygen/hydrogen, and/or electron, gain/loss (calculation of oxidation numbers is **not** required)

(d) describe the use of aqueous potassium iodide in testing for oxidising agents and acidified potassium manganate(VII) in testing for reducing agents from the resulting colour changes

6.3 Reversible reactions

(a) describe the idea that some chemical reactions can be reversed by changing the reaction conditions

(b) describe the idea that some reversible reactions can reach dynamic equilibrium and predict and explain the effect of changing the conditions (see 7.3(b) and 7.3(c))

Reaction Kinetics
or
Rate of reaction

Rate of reation or speed of reaction (Definition)

- The time taken by the reactants to be converted into products is called the rate of reaction.

$$\text{Rate} = \frac{\text{Decrease in amount of reactants or Increase in amount of products}}{\text{Time}}$$

Indications of chemical reactions

1) Evolution of gas (effervescence)
2) Change in colours
3) Formation of precipitates
4) Change in temperature
5) Change in pH (Example neutralisation reaction)

How to measure the rate of a chemical reaction?

1) By measuring decrease in mass
2) By collecting volume of gas evolved

Measurement of a rate of reaction by measuring decrease in mass

$$CaCO_{3(s)} + 2HCl_{(aq)} \longrightarrow CaCl_{2(aq)} + H_2O_{(l)} + CO_{2(g)}$$

CO_2 produced causes a decrease in mass → The greater the volume of CO_2 produced greater will be the decrease in mass

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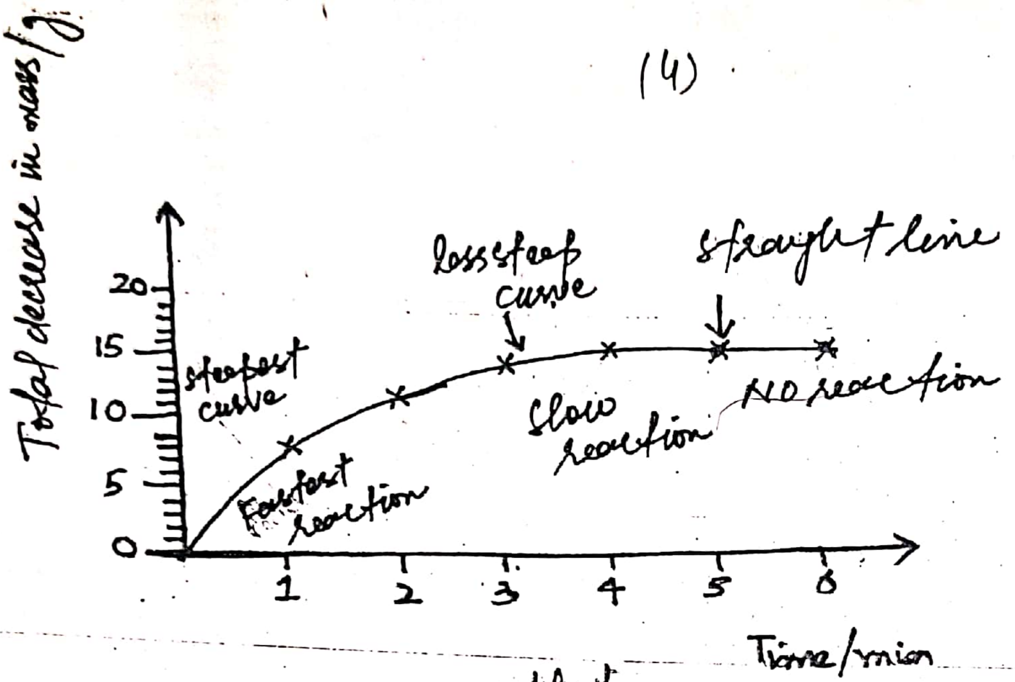
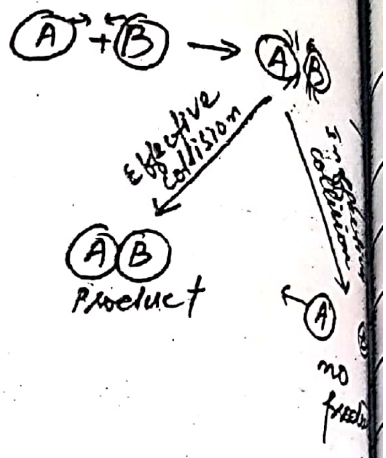
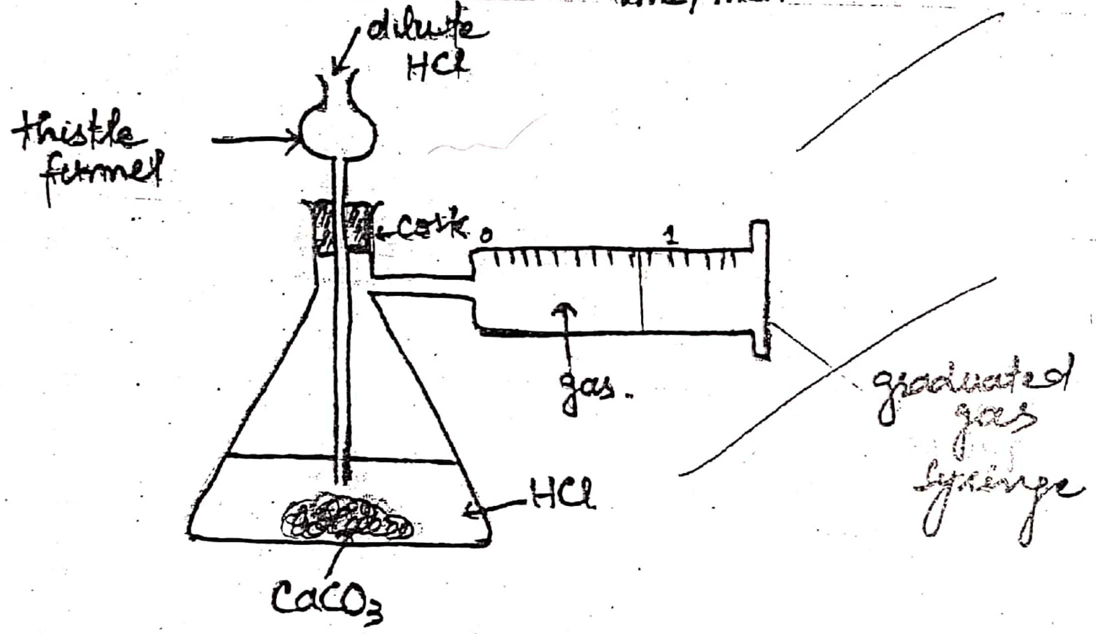
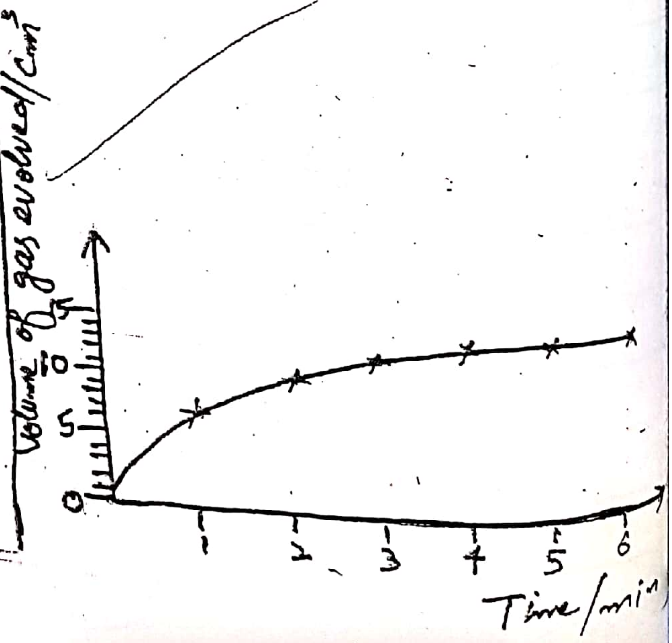






Time/min	Volume of gas/cm^3	Volume of gas/min
0	0	00
1	7	07
2	10	03
3	12	02
4	13	01
5	13	00
6	13	00



Measuring rate of reaction by measuring volume of gas

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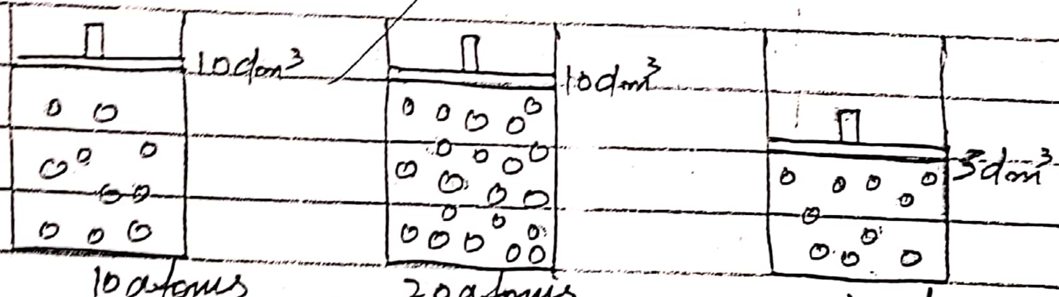
Factors affecting the rate of reaction in the light of collision theory

Collision Theory: According to collision theory, rate of a chemical reaction depends upon frequency of collisions. Greater the frequency of collisions, faster will be the rate of reaction and vice versa.

Effect of temperature on the rate of reaction in the light of C.T

- Increase in temperature increases the kinetic energy of the reacting particles and particles start moving faster and collide more frequently. This increases the rate of reaction.

Effect of concentration "



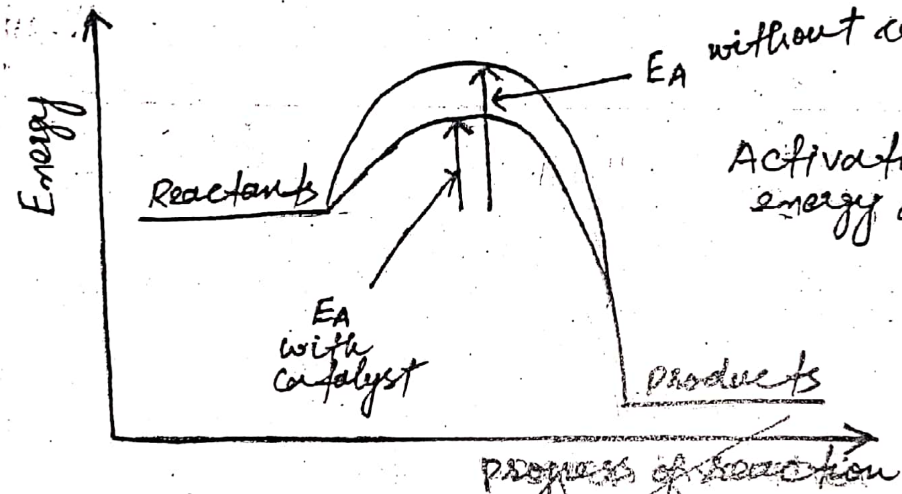
10 atoms	20 atoms	10 atoms
A	B	C
1 atom/dm^3	2 atom/dm^3	2 atom/dm^3

(B and C: same concentration)

- With the increase in concentration, particles get closer together hence collide more frequently and the rate of reaction increases.

A + B ⟶ AB 20J] → 20J without catalyst

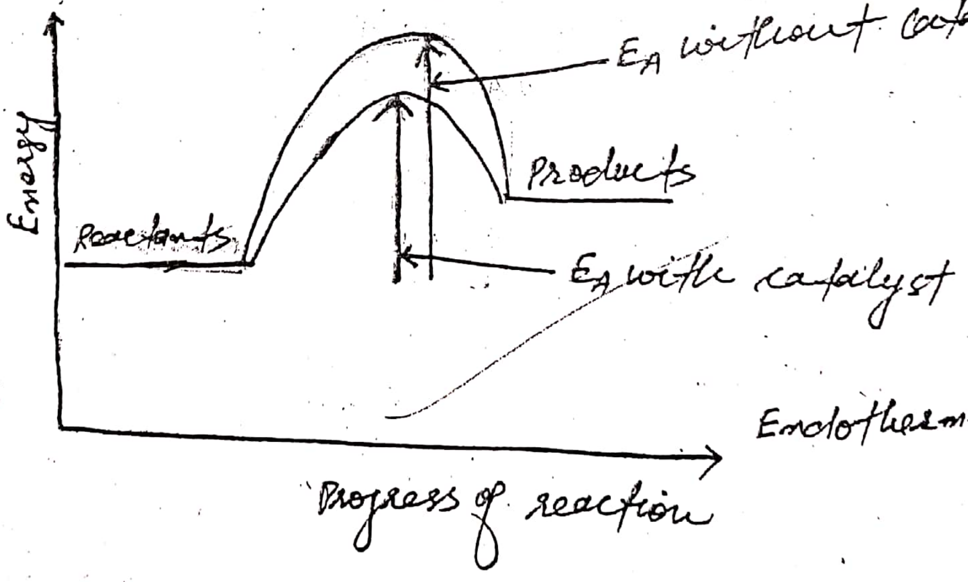
A + C ⟶ AC 5J
AC + B ⟶ AB + C 5J] 10J with catalyst



Activation energy decreases

Exothermic reaction

E_A = Activation energy

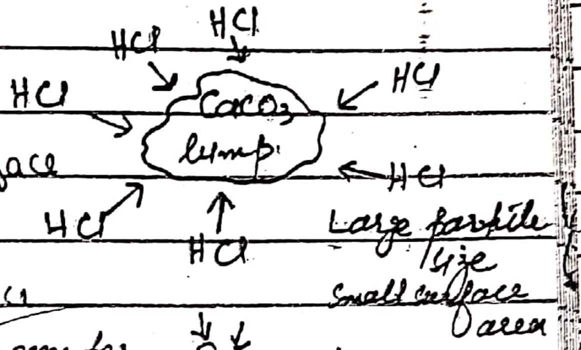


Endothermic

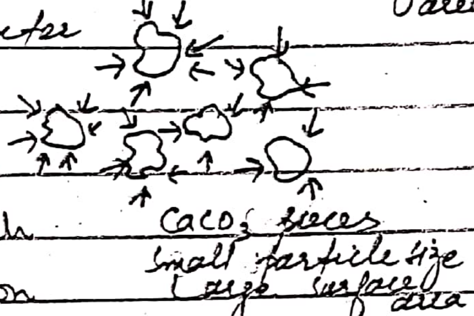
Effect of Pressure : (applicable for only gases)

With the increase in pressure, particles get closer together, hence collide more frequently, therefore the rate of the reaction also increases.

Effect of Surface Area :



- Large particle size, smaller the surface area, slower the reaction.
- Small particle size, larger the surface area, faster the reaction, due to greater frequency of collisions



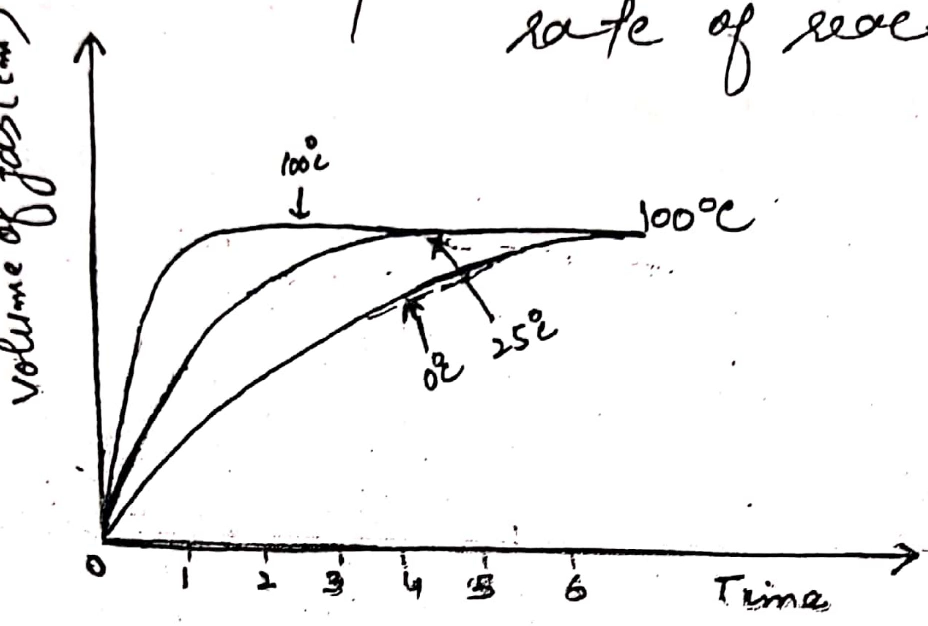
Effect of Catalyst :

Catalyst :- Are those substances which speed up a chemical reaction without being chemically changed (used up) during chemical reaction

- Catalysts may undergo a physical change during a chemical reaction. For example catalysts may have a change in its state (granules → powder), shape, look (appearance) (shiny → dull) etc.

- Catalysts speed up a chemical reaction by decreasing the activation energy of the reaction and by providing an alternate pathway for the reaction
- Enzymes are biological catalyst that speed up a chemical reaction without being chemically changed at the end of the reaction

Graphical representation of rate of reaction



Reversible and Irreversible reactions

Irreversible reactions

Those reactions which proceed only in one direction i.e, in which only reactants are converted into products but products don't turn back into reactants.

Example

Reaction of metals with acids, neutralisation reactions, combustion reactions etc.

$$Mg + 2HCl \longrightarrow MgCl_2 + H_2$$

- They are represented by simple arrow

Reversible reactions

Those reactions which proceed in both directions simultaneously i.e, in which not only reactants are converted into products but products also turn back to reactants

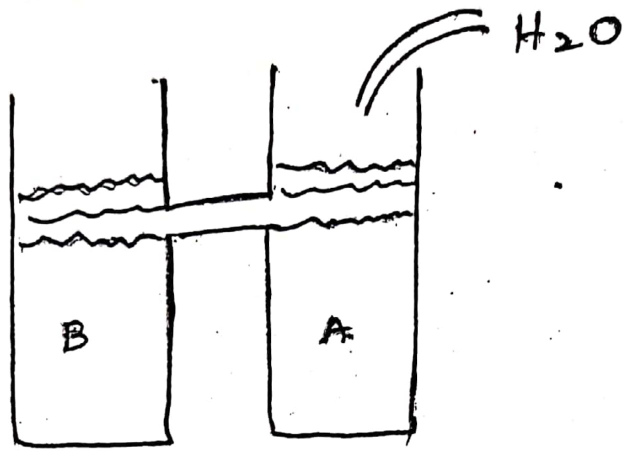
Example

$$N_2 + 3H_2 \underset{200\text{-}300\ atm}{\overset{Fe/450°C}{\rightleftharpoons}} 2NH_3 \quad -\Delta H$$

- Reversible reactions are represented by double arrow.

Dynamic Equilibrium

- When the rate of forward reaction becomes equal to the rate of backward reaction, this state is called "dynamic equilibrium".
- Dynamic equilibrium does not mean equal concentration of



water level does not change

If more H_2O in A (A → B)
if H_2O is taken from B (A → B)

reactants and products, but equal ~~rate~~ speed/ of ~~forward and~~ ~~backward~~ reaction

- At dynamic equilibrium, reactions ~~remains~~ continue but concentration of reactants and products ~~becoming~~/constant.
- Dynamic equilibrium is the ultimate goal of all reversible reaction

Effect of Concentration

Increase in the concentration of the reactants or decrease in the concentration of the products increases the speed of forward reaction and shifts dynamic equilibrium towards forward direction and increases the yeild of products

Effect of pressure

Increase in pressure or decrease in volume shift dynamic equilibrium toward the side where there are lesser number of moles (lesser volume) and vice versa

Example (1) $N_2 + 3H_2 \underset{200\ atm}{\rightleftharpoons} 2NH_3$

4 moles — 2 moles

$96\ dm^3$ — $48\ dm^3$

Increase in pressure will shift the equilibrium towards the product side as there are lesser number of moles at product side and will increase the yield of ammonia.

* It is only applicable for gases ...

Important point

$$N_2 + 3H_2 \rightleftharpoons 2NH_3 \quad -\Delta H$$

With the increase in temperature, rate of both forward and backward reaction is increased but increase in the rate of endothermic (backward) reaction is greater than the increase in the rate of exothermic (forward) reaction.

Therefore dynamic equilibrium is shifted towards backward direction with the increase in temperature.

(03)

(2) $N_2O_4 \rightleftharpoons N_2 + 2O_2$

1 moles — 3 moles.

High pressure will shift the equilibrium towards backwards direction (reactant side).

Effect of temperature

Endothermic reactions absorbed heat and are favoured by high temperatures

Exothermic reactions released heat and are favoured by low temperatures.

High temperature shifts dynamic equilibrium towards forward direction in endothermic reaction and towards backward direction in exothermic reaction.

Example:

$$\text{Ice} \underset{0°C}{\overset{0°C}{\rightleftharpoons}} \text{Water}$$

endothermic (1°C) — exothermic (-1°C)

At 0°C both forward & backward processes will take place

Effect of catalyst

Catalyst does not effect the dynamic equilibrium, it only helps to attain dynamic equilibrium in shorter period of time by equally increasing the speed of forward and backward reaction

...nesday 1st December, 2010

Redox Reactions

Oxidation Number or Oxidation State

It is a charge present over a element in a compound which may be equal or may not be equal to the valency of that element

Rules for assigning oxidation numbers to the

1) All elements in their free or uncombined state have zero oxidation number E.g :- Na^0, Cl_2^0, O_2^0

2) Sum of the oxidation states of all elements present in a compound must be equal to zero. E.g :- Na^+Cl^- $(+1+^{-1}=0)$, $Mg^{+2}O^{-2}$ $(+2)+(-2) = 0$

3) Oxidation number of hydrogen is +1 in it's covalent compound and -1 in it's ionic compounds E.g :- H^+Cl^-, Na^+H^-, $Mg^{+2}H_2^{-1}$
Ionic compounds of hydrogen are called hydrides.
E.g :- $Al^{+3}H_3^{-1}$

4) Oxidation number of oxygen is -2 in most of it's compounds which are called oxides. E.g :- $Mg^{+2}O^{-2}$, $H_2^{+}O^{-2}$

5) Oxidation number of oxygen is -1 in its peroxides.
E.g :- $H_2^{+1}O_2^{-1}$, $Na_2^{+1}O_2^{-1}$, $K_2^{+1}O_2^{-1}$

$K^{+} O_2^{-1/2}$

$+1 + 2 \times -\frac{1}{2} = 0$

$+1 - 1 = 0$

Group 4

+4 → metal, −4 → nonmetals

HNO_3

See middle element & make its oxygen no. in end

First see side elements & determine their oxidation no.

When Oxygen combines with metal of Group 1, oxidation state ($-\frac{1}{2}$)

don't write (~~-0.5~~)

More reactive non-metal will have its oxidation state (−).

$C^{+2}O^{-2}$ → more reactive

6) Oxidation state of oxygen is $-\frac{1}{2}$ in it's superoxides.
Eg $K^{+1}O_2^{-1/2}$ (Potassium Super Oxide) (only for grp I)
$Na^{+}O_2^{-1/2}$ $Li^{+1}O_2^{-1/2}$

7) Oxidation number of elements present in group I, II, III is +1, +2, +3 respectively. Valency will be equal to oxidation state of groups I, II, III except Boron which has -3 oxidation number (also it's valency).

8) Elements present in group 4 - 7 have variable oxidation numbers. One of their oxidation number is equal to their valency and their other oxidation number will be equal to their group number and that will be positive.

Examples:-

IV	V	VI	VII
C	N	O	F
		S	Cl
$\overset{+4}{C}\overset{-2}{O_2}$	$\overset{-3}{N}\overset{+1}{H_3}$	$\overset{+}{H_2}\overset{-2}{S}$	$\overset{+}{H}Cl^{-}$
$\overset{-4}{C}\overset{+1}{H_4}$	$\overset{+1}{H}\overset{+5}{N}\overset{-2}{O_3}$	$\overset{+6}{S}\overset{-2}{O_3}$	$\overset{+}{H}\overset{+7}{Cl}\overset{-2}{O_4}$
$\overset{+2}{C}\overset{-2}{O}$	$\overset{+2}{N}\overset{-2}{O}$	$\overset{+4}{S}\overset{-2}{O_2}$	$\overset{+}{H}\overset{+5}{Cl}\overset{-2}{O_3}$
	$\overset{+4}{N}\overset{-2}{O_2}$	$\overset{+1}{H_2}\overset{+6}{S}\overset{-2}{O_4}$	$\overset{+}{H}\overset{+3}{Cl}\overset{-2}{O_2}$
	$\overset{+1}{N_2}\overset{-2}{O}$		$H\overset{+1}{Cl}O^{-2}$

9) Sum of the oxidation states of all the elements present in a radical (charge containing species) must be equal to the charge present over the radical. E.g. :- NO_3^{-1} $(\overset{+5}{N}\overset{-2}{O_3})^{-1}$, SO_4^{-2} $(\overset{+6}{S}\overset{-2}{O_4})^{-2}$, CO_3^{-2} $(\overset{+4}{C}\overset{-2}{O_3})^{-2}$

$K_2Cr_2O_7$

$2(K) + 2(Cr) + 7(O) = 0$

$2(+1) + 2Cr + 7(-2) = 0$

$+2 + 2Cr - 14 = 0$

$-12 + 2Cr = 0$

$2Cr = 12$

$Cr = \frac{12}{2} = 6$

$Cr = +6$

Identify the oxidation number of the underlined elements in the following compounds

i) $Cr_2^{+3}O_3^{-2}$

ii) $Cr^{+2}Cl_2^{-}$

iii) $K_2^{+1}Cr^{+6}O_4^{-2}$

iv) $K_2^{+1}Cr_2^{+3}O_7^{-2}$ $K_2^{+1}Cr_2^{+6}O_7^{-2}$

v) $K^{+1}Mn^{+7}O_4^{-2}$

vi) PO_4^{-3} $(P^{+5}O_4^{-2})^{-3}$

vii) $P_2^{+5}O_5^{-2}$

viii) $Fe^{+2}SO_4^{-2}$ $Fe^{+2}(SO_4)^{-2}$

ix) $Cu_2^{+1}O^{-2}$

x) $F_2^{+1}O^{-2}$ $F^{-1}O^{+2}$ (only compound with Oxygen's oxidation state +2)

xi) $Na_2^{+2}O_2^{-2}$ $Na_2^{+1}O_2^{-1}$

xii) $Be^{+1}O_2^{-2}$ $Be^{+2}O_2^{-1}$

08/12

07/12/2010

Oxidation	Reduction
1) Addition of oxygen: $C + O_2 \longrightarrow CO_2$	1) Removal of oxygen $Fe_2O_3 \longrightarrow Fe + O_2$
2) Removal of hydrogen $CaH_2 \xrightarrow{heat} Ca + H_2$	2) Addition of hydrogen $C_2H_4 + H_2 \longrightarrow C_2H_6$
3) Loss of electron $Na_{(s)} \longrightarrow Na^{+1} + 1\bar{e}$	3) Gain of electrons $F_{(g)} + 1\bar{e} \longrightarrow F^-$
Increase in oxidation number or oxidation state	Decrease in oxidation number or oxidation state

Oxidising agents and Reducing Agents

Oxidising agents or oxidants

- These substances which oxidise other substances either by giving oxygen, by removing hydrogen or by removing electrons.
- Oxidising agents themselves get reduced

Reducing agents or reductants

- Those substances which reduce other substances either by removing/taking oxygen, by giving hydrogen or by giving electrons.
- Reducing agents themselves get oxidized.

$Fe_2O_3 + CO \longrightarrow Fe + CO_2$

→ Identify the substance oxidised. Give reason

CO because it gained oxygen

→ Identify the substance reduced. Give reason

Fe_2O_3, as it has lost oxygen

→ Identify oxidising agent. Give reason

Fe_2O_3 because it oxidised CO by giving oxygen.

→ Identify reducing agent. Give reason

CO, because it has reduced Fe_2O_3 by taking its oxygen.

Common oxidising and reducing agents

Oxidising agents	Reducing agents
⇒ Non-metals because they gain electrons	⇒ Metals because they loose electrons
⇒ oxygen (O_2)	⇒ Hydrogen (H_2)
⇒ Acidified Potassium manganate (VII) Turns from Pink or Purple to colourless when reacts with a reducing agent.	⇒ Aqueous KI It itself colourless but when it reacts with an oxidising agent it turns brown
☆⇒ Acidified Potassium dichromate (VI) Turns from orange to green when reacts with a reducing agent	⇒ Aqueous Iron(II) sulphate $FeSO_4 \longrightarrow Fe_2(SO_4)_3$ Iron(II) sulphate Green — reddish Brown Iron(III) sulphate

Y(O6)

$$\overset{+3}{Fe_2}\overset{-2}{O_3} + \overset{+2}{C}\overset{-2}{O} \longrightarrow Fe + \overset{+4}{C}\overset{-2}{O_2}$$

Identify with respect to electrons or oxidation number

$Fe^{+3} + 3\bar{e} \longrightarrow Fe^{0}$

$C^{+2} \longrightarrow C^{+4} + 2\bar{e}$

⇒ Oxidised

Carbon, because it lost electrons

⇒ reduced

Iron (Fe) because it gained electrons

⇒ oxidising agent

Fe (Iron) because it oxidised carbon by taking its electrons.

⇒ Reducing agent

C (carbon), because it has reduced iron by giving electrons

Excellent

[signature]

01/12/2020

Thursday 20th January 2011

Redox Reactions

Q Write the oxidation number of underlined elements :-

$\underline{Mg}^{+2}O^{-2} = +2$	$\underline{Cu}_2^{+1}O^{-2} = +1$	$H_2^{+1}\underline{O_2}^{-1} = -1$
$\underline{Al}_2^{+3}O_3^{-2} = +3$	$\underline{S}^{+4}O_2^{-2} = +4$	$Na_2^{+1}\underline{O_2}^{-1} = -1$
$\underline{Fe}^{+2}Cl_2^{-1} = +2$	$\underline{S}^{+6}O_3^{-2} = +6$	$K^{+1}\underline{O_2}^{-1/2} = -\frac{1}{2}$
$Mg^{+2}\underline{S}^{-2} = -2$	$\underline{C}^{+2}O^{-2} = +2$	$\underline{N}^{+4}O_2^{-2} = +4$
$\underline{C}^{-4}H_4^{+1} = -4$	$Mg^{+2}\underline{H}_2^{-1} = -1$	$\underline{N}^{+2}O^{-2} = +2$
$\underline{C}^{+4}O_2^{-2} = +4$	$Al^{+3}\underline{H}_3^{-1} = -1$	$\underline{N}_2^{+1}O^{-2} = +1$
$\underline{Cl_2} = 0$		

3rd February, 2011

Redox Reactions

Q1 $ZnO + CO \longrightarrow Zn + CO_2$

(a) Identify the substance oxidised with respect to oxygen. Give reasons (2)

Ans CO has been oxidised because it has gained oxygen.

(b) Identify the substance reduced with respect to oxygen. Give reasons. (2)

Ans ZnO has been reduced because it has lost oxygen.

(c) Identify the oxidising agent with respect to oxygen. Give reasons. (2)

Ans ZnO is the oxidising agent as it has oxidised CO to CO_2 by giving it oxygen.

(d) Identify the reducing agent with respect to oxygen. Give reasons (2)

Ans CO is the reducing ~~bagent~~ because it has reduced ZnO to Zn by taking it's oxygen.

Q2 $\overset{+2}{Zn}\overset{-2}{O} + \overset{+2}{C}\overset{-2}{O} \longrightarrow \overset{0}{Zn} + \overset{+4}{C}\overset{-2}{O_2}$

(a) Identify the substance oxidised with respect to electrons. Give reasons. (2)

Ans Carbon has been oxidised because it has lost electrons.

(b) Identify the substance reduced with respect to electrons. Give reasons (2)

Ans Zn has been reduced because it has gained two electrons

(c) Identify the oxidising agent with respect to electrons. Give reas

Ans Zn is the oxidising agent because It has oxidised carbon by taking electrons (O.no: It has increased oxidation number of carb

(d) Identify the reducing agent with respect to electrons. Give reasons. (2)

Ans C is the reducing agent because it has reduced zinc by giving its electrons

Q3 $\overset{0}{Cl_2}_{(aq)} + \overset{+}{K}Br^{-}_{(aq)} \longrightarrow K^{+}Cl^{-}_{(aq)} + \overset{0}{Br_2}_{(aq)}$

(a) Identify the substance oxidised with respect to oxidation numbers. Give reasons (2)

Ans Br has been oxidised because it's oxidation number has increased from -1 to 0

(b) Identify the substance reduced with respect to oxidation number. Give reason. (2)

Ans Cl has been reduced because its oxidation number has decreased from 0 to -1

(c) Identify the oxidising agent with respect to oxidation number. Give reason. (2)

Ans Cl is the oxidising agent because it has increased the oxidation number of Br from -1 to 0.

(d) Identify the reducing agent with respect to oxidation number. Give reason. (2)

Ans: Br is the reducing agent because it has decreased the oxidation number of Cl from 0 to -1

Q4 $\overset{+3}{Fe_2}\overset{-2}{O_3} + \overset{+2}{C}\overset{-2}{O} \longrightarrow Fe^{0} + \overset{+4}{C}\overset{-2}{O_2}$

(a) Identify the substance oxidised with respect to electrons. Give reasons. (2)

Ans: C has been oxidised because it has lost two electrons.

(b) Identify the substance reduced with respect to electrons. Give reasons (2)

Ans: Fe has been reduced because it has gained three electrons

(c) Identify the oxidising agent with respect to electrons. Give reasons (2)

Ans: Fe is the oxidising agent because it has oxidised C by taking two electrons from it.

(d) Identify the reducing agent with respect to electrons. Give reasons. (2)

Ans: C is the reducing agent because it has reduced Fe by giving ~~three electrons~~ from it.

Thursday 27th January 201

Test

Oxidation Numbers

Assign oxidation number to the underlined elements.

1) $P_2^{+3}O_3^{-2}$ = +3

2) $P_2^{+5}O_5^{-2}$ = +5

3) $H^{+}Br^{+}O^{-2}$ = +1

4) $Al^{+3}H_3^{-}$ = −1

5) $B^{+3}F_3^{-}$ = +3

6) $(Mn^{+7}O_4^{-2})^{-1}$ = +7

15) $H_2^{+}Si^{+4}O_3^{-2}$ = +4

7) $H_2^{+}S^{+4}O_3^{-2}$ = +4

8) $H^{+}N^{+3}O_2^{-2}$ = +3

9) $P^{-3}H_3^{+}$ = +1

10) $Cu_2^{+}O^{-2}$ = +1

11) $K^{+}Cl^{+5}O_3^{-2}$ = +5

12) $H_3^{+}P^{+5}O_4^{-2}$ = +5

13) $Be^{+2}O_2^{-}$ = −1

14) $Rb^{+}O_2^{-1/2}$ = −1/2