My name is Subhashish Chattopadhyay. I have been teaching for IIT-JEE, Various International Exams (such as IMO [International Mathematics Olympiad], IPhO [International Physics Olympiad], IChO [International Chemistry Olympiad]), IGCSE (IB), CBSE, I.Sc, Indian State Board exams such as WB-Board, Karnataka PU-II etc since 1989. As I write this book in 2016, it is my 25th year of teaching. I was a Visiting Professor to BARC Mankhurd, Chembur, Mumbai, Homi Bhabha Centre for Science Education (HBCSE) Physics Olympics camp BARC Campus.
I am Life Member of ...
- IAPT (Indian Association of Physics Teachers)
- IPA (Indian Physics Association)
- AMTI (Association of Mathematics Teachers of India)
- National Human Rights Association
- Men’s Rights Movement (India and International)
- MGTOW Movement (India and International)

And also of

IACT (Indian Association of Chemistry Teachers)

The selection for National Camp (for Official Science Olympiads - Physics, Chemistry, Biology, Astronomy) happens in the following steps ...

1) NSEP (National Standard Exam in Physics) and NSEC (National Standard Exam in Chemistry) held around 24th November. Approx 35,000 students appear for these exams every year. The exam fees is Rs 100 each. Since 1998 the IIT JEE toppers have been topping these exams and they get to know their rank / performance ahead of others.

2) INPhO (Indian National Physics Olympiad) and INChO (Indian National Chemistry Olympiad). Around 300 students in each subject are allowed to take these exams. Students coming from outside cities are paid fair from the Govt of India.

3) The Top 35 students of each subject are invited at HBCSE (Homi Bhabha Center for Science Education) Mankhurd, near Chembur, BARC, Mumbai. After a 2-3 weeks camp the top 5 are selected to represent India. The flight tickets and many other expenses are taken care by Govt of India.
Since last 50 years there has been no dearth of “Good Books”. Those who are interested in studies have been always doing well. This e-Book does not intend to replace any standard text book. These topics are very old and already standardized.

There are 3 kinds of Text Books

- The thin Books - Good students who want more details are not happy with these. Average students who need more examples are not happy with these. Most students who want to “Cram” quickly and pass somehow find the thin books “good” as they have to read less !

- The Thick Books - Most students do not like these, as they want to read as less as possible. Average students are “busy” with many other things and have no time to read all these.

- The Average sized Books - Good students do not get all details in any one book. Most bad students do not want to read books of “this much thickness“ also !

We know there can be no shoe that’s fits in all.

Printed books are not e-Books! Can’t be downloaded and kept in hard-disc for reading “later” ........

So if you read this book later, you will get all kinds of examples in a single place. This becomes a very good “Reference Material”. I sincerely wish that all find this “very useful”.

Students who do not practice lots of problems, do not do well. The rules of “doing well” had never changed .... Will never change !

In this e-Book I am trying to solve this problem. Those students who practice can learn.

No one can help those who are not studying, or practicing.
A very polite request:

I wish these e-Books are read only by Boys and Men. Girls and Women, better read something else; learn from somewhere else.
Preface

We all know that in the species “Homo Sapiens “, males are bigger than females. The reasons are explained in standard 10, or 11 ( high school ) Biology texts. This shapes or size, influences all of our culture. Before we recall / understand the reasons once again, let us see some random examples of the influence

Random - 1

If there is a Road rage, then who all fight ? ( generally ? ). Imagine two cars driven by adult drivers. Each car has a woman of similar age as that of the Man. The cars “ touch “ or “ some issue happens”. Who all comes out and fights ? Who all are most probable to drive the cars ?

( Men are eager to fight, eager to rule, eager for war. Men want to drive. Men want to win )

Random - 2

Heavy metal music artists are all Men. Metallica, Black Sabbath, Motley Crue, Megadeth, Motorhead, AC/DC, Deep Purple, Slayer, Guns & Roses, Led Zeppelin, Aerosmith ..... the list can be in thousands. All these are grown-up Boys, known as Men.

( Men strive for perfection. Men are eager to excel. Men work hard. Men want to win. )

Random - 3

Apart from Marie Curie, only one more woman got Nobel Prize in Physics. ( Maria Goeppert Mayer - 1963 ). So, ... almost all are men.

Random - 4

The best Tabla Players are all Men.

Boys start fighting from school days. Girls do not fight like this.
Random - 6

The highest award in Mathematics, the "Fields Medal" is around since decades. Till date only one woman could get that. (Maryam Mirzakhani - 2014). So, ... almost all are men.

Random - 7

Actor is a gender neutral word. Could the movie like "Top Gun" be made with Female actors? The best pilots, astronauts, Fighters are all Men.
In my childhood had seen a movie named “The Tower in Inferno”. In the movie when the tall tower is in fire, women were being saved first, as only one lift was working.

Many decades later another movie is made. A box office hit. “The Titanic”. In this also .... As the ship is sinking women are being saved. Men are disposable. Men may get their turn later...
Movies are not training programs. Movies do not teach people what to do, or not to do. Movies only reflect the prevalent culture. Men are disposable, is the culture in the society. Knowingly, unknowingly, the culture is depicted in Movies, Theaters, Stories, Poems, Rituals, etc. I or you can’t write a story, or make a movie in which after a minor car accident the Male passengers keep seating in the back seat, while the both the women drivers come out of the car and start fighting very bitterly on the road. There has been no story in this world, or no movie made, where after an accident or calamity, Men are being helped for safety first, and women are told to wait.

Random - 9

Artists generally follow the prevalent culture of the Society. In paintings, sculptures, stories, poems, movies, cartoon, Caricatures, knowingly / unknowingly, “the prevalent Reality“ is depicted. The opposite will not go well with people. If deliberately “the opposite“ is shown then it may only become a special art, considered as a special mockery.

Random - 10

Men go to “girl / woman’s house” to marry / win, and bring her to his home. That is a sort of winning her. When a boy gets a “Girl-Friend”, generally he and his friends consider that as an achievement. The boy who “got / won” a girl-friend feels proud. His male friends feel, jealous, competitive and envious. Millions of stories have been written on these themes. Lakhs of movies show this. Boys / Men go for “bike race”, or say “Car Race “, where the winner “gets“ the most beautiful girl of the college.

( Men want to excel. Men are eager to fight, eager to rule, eager for war. Men want to drive. Men want to win. )

Prithviraj Chauhan ‘ went ` to “pickup” or “abduct” or “win” or “ bring “ his love. There was a Hindi movie (hit ) song … “ Pasand ho jaye, to ghar se utha laye “. It is not other way round. Girls do not go to Boy’s house or man’s house to marry. Nor the girls go in a gang to “pick-up“ the boy / man and bring him to their home / place / den.

CBSE Standard 12 Chemistry Survival Guide - Reduction Methods by Prof. Subhashish Chattopadhyay
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Random - 11

Rich people; often are very hard working. Successful business men, establish their business (empire), amass lot of wealth, with lot of difficulty. Lots of sacrifice, lots of hard work, gets into this. Rich people’s wives had no contribution in this wealth creation. Women are smart, and successful up to the extent to choose the right/rich man to marry. So generally what happens in case of Divorces? Search the net on “most costly divorces” and you will know. The women; (who had no contribution at all, in setting up the business/empire), often gets in Billions, or several Millions in divorce settlements.

Number 1

Rupert & Anna Murdoch -- $1.7 billion

One of the richest men in the world, Rupert Murdoch developed his worldwide media empire when he inherited his father’s Australian newspaper in 1952. He married Anna Murdoch in the ‘60s and they remained together for 32 years, springing off three children.

They split amicably in 1998 but soon Rupert forced Anna off the board of News Corp and the gloves came off. The divorce was finalized in June 1999 when Rupert agreed to let his ex-wife leave with $1.7 billion worth of his assets, $115 million of it in cash. Seventeen days later Rupert married Wendi Deng, one of his employees.


See http://skmclasses.kinja.com/save-the-male-1761788732

It was Boys and Men, who brought the girls/women home. The Laws are biased, completely favoring women. The men are paying for their own mistakes.

See https://zookeepersblog.wordpress.com/biased-laws/

(Man brings the Woman home. When she leaves, takes away her share of big fortune!)

Random - 12

A standardized test of Intelligence will never be possible. It never happened before, nor ever will happen in future; where the IQ test results will be acceptable by all. In the net there are thousands of charts which show that the intelligence scores of girls/women are lesser. Debates of Trillion words, does not improve performance of Girls.
I am not wasting a single second debating or discussing with anyone, on this. I am simply accepting ALL the results. IQ is only one of the variables which is required for success in life. Thousands of books have been written on “Networking Skills“, EQ (Emotional Quotient), Drive, Dedication, Focus, “Tenacity towards the end goal“… etc. In each criteria, and in all together, women (in general) do far worse than men. Bangalore is known as “….. capital of India“.[ Fill in the blanks ]. The blanks are generally filled as “Software Capital“, “IT Capital“, “Startup Capital“, etc. I am member in several startup eco-systems/groups. I have attended hundreds of meetings, regarding “technology startups“, or “idea startups“. These meetings have very few women. Starting up new companies are all “Men’s Game“/“Men’s business“. Only in Divorce settlements women will take their goodies, due to Biased laws. There is no dedication, towards wealth creation, by women.

Random - 13

Many men, as fathers, very unfortunately treat their daughters as “Princess“. Every “non-performing“ woman / wife was “princess daughter“ of some loving father. Pampering the girls, in name of “equal opportunity“, or “women empowerment“, have led to nothing.


There can be thousands of more such random examples, where “Bigger Shape / size“ of males have influenced our culture, our Society. Let us recall the reasons, that we already learned in standard 10 - 11, Biology text Books. In humans, women have a long gestation period, and also spends many years (almost a decade) to grow, nourish, and stabilize the child. (Million years of habit) Due to survival instinct Males want to inseminate. Boys and Men fight for the “facility (of womb + care)“ the girl / woman may provide. Bigger size for males, has a winning advantage. Whoever wins, gets the “woman / facility“. The male who is of “Bigger Size“, has an advantage to win…. Leading to Natural selection over millions of years. In general “Bigger Males“; the “fighting instinct“ in men; have led to wars,
and solving tough problems (Mathematics, Physics, Technology, startups of new businesses, Wealth creation, Unreasonable attempts to make things [such as planes], Hard work ...)

So let us see the IIT-JEE results of girls. Statistics of several years show that there are around 17, (or less than 20) girls in top 1000 ranks, at all India level. Some people will yet not understand the performance, till it is said that... year after year we have around 980 boys in top 1000 ranks. Generally we see only 4 to 5 girls in top 500. In last 50 years not once any girl topped in IIT-JEE advanced. Forget about Single digit ranks, double digit ranks by girls have been extremely rare. It is all about good boys, hard working, focused, Bel-esprit boys.

In 2015, Only 2.6% of total candidates who qualified are girls (upto around 12,000 rank), while 20% of the Boys, amongst all candidates qualified. The Total number of students who appeared for the exam were around 1.4 million for IIT-JEE main. Subsequently 1.2 lakh (around 120 thousands) appeared for IIT-JEE advanced.

IIT-JEE results and analysis, of many years is given at https://zookeepersblog.wordpress.com/iit-jee-iseet-main-and-advanced-results/

In Bangalore it is rare to see a girl with rank better than 1000 in IIT-JEE advanced. We hardly see 6-7 boys with rank better than 1000. Hardly 2-3 boys get a rank better than 500.

See http://skmclasses.weebly.com/everybody-knows-so-you-should-also-know.html

Thousands of people are exposing the heinous crimes that Motherly Women are doing, or Female Teachers are committing. See https://www.facebook.com/WomenCriminals/

Some Random Examples must be known by all

It is extremely unfortunate that the *woman empowerment* has created. This is the kind of society and women we have now. And many other sensible men hate such women. Be away from such women, be aware of reality.

"Sex with my son is incredible - we’re in love and we want a baby"
Ben Ford, who ditched his wife when he met his mother Kim West after 30 years, claims what the couple are doing isn’t incest.

Mother Admits On Facebook to Sleeping with 15 Yr Old Son, They Have a Baby Together - AlwaysTurnUp

Sometimes it hard to believe w/FromAlwaysTurnUp
Up to 64,000 women in UK are child-sex offenders

The Guardian

In fact, the past decade has seen a dramatic increase in the number of incidents of women raping and sexually assaulting boys and men. On May 14, Jacob Rees...

End Violence against women....

North Carolina Grandma Eats Her Daughter’s New Born Baby After Snorting Bath Salts

Henderson, North Carolina—A North Carolina grandmother of 4 and recovering drug addict, is now in custody after she allegedly ate her daughter's newborn baby...

28-Year-Old Texas Teacher Accused of Sending Nude Picture to 14-Year-Old Former Student

Breitbart.com

http://www.wnji.com/.../attractive-girl-gang-lured-men-alleywa...

http://www.wnji.com/.../youngstown-woman-convicted-of-rapea...

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Women are raping boys and young men
Rape advocacy has been reignited and belied to a political agenda controlled by radicalized activists. Tim Patten takes a no-kneen and well-supported look into the manufactured rape culture and...

A Russian-born newlywed slowly but surely her German husband — feeding strips of his flesh to their dog until he took his last breath. Svetlana Batikova, 46, was...

See More

Bronx Woman Convicted of Poisoning and Drowning Her Children
Lisa Lee Barnaages researched methods on the Internet before she killed her son and daughter in 2012.

Daily Mail
January 15, 2015

Mother charged with rape and sodomy of her son's 12-year-old friend

She killed her husband and then fed him to her dog: police
A Russian-born newlywed butchered her German hubby — and fed strips of his flesh to their dog until he took his last breath. Svetlana Batikova, 46, was...

Mom, 30, raped and had oral sex with her son's 12-year-old friend
Mother Marie Smith, 30, (picture) of St Charles County, Missouri, has been jailed after she allegedly targeted the 12-year-old boy at her home.

Female prison officers commit 90pc of sex assaults on male teens in US juvenile detention centres
Lawbreak in Idaho highlights the prevalence of sexual exploitation of juvenile offenders.

Mother Who Filmed Herself Raping Her 1-Year-Old Son Receives Shocking Sentence
"... than send the money to buy herself's jewelry."

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In several countries or rather in several regions of the world, family system has collapsed, due to bad nature and naughty acts of women. Particularly in Britain, and America, almost 50% people are alone, lonely, separated, divorced or failed marriages. In 2013, 48% children were born out of wedlock. It was projected that by 2016, more than 51% children will be born, to unmarried mothers. In these developed countries 'paternity fraud' by women, are close to 20%. You can see several articles in the net, and in wikipedia etc. This means 1 out of 5 children are calling a wrong man as dad. The lonely, alone "mothers" are frustrated. They see the children as burden. Love in the Society in general is lost, long time ago. The types of "Mothers" and "Women" we have now ............

This is the type of women we have in this world. These kind of women were also someone's daughter.

Mother Stabs Her Baby 90 Times With Scissors After He Bit Her While Breastfeeding Him!

Eight-month-old Mao Ru was discovered by his uncle in a pool of blood. Needed 100 stitches after the incident; he is now recovering in hospital. Reports say hot...
HURT FEMINISM BY DOING NOTHING

- Don’t Help Women
- Don’t Fix Things for Women
- Don’t Support Women’s Issues
- Don’t Come to Women’s Defense
- Don’t Speak for Women
- Don’t Value Women’s Feelings
- Don’t Portray Women as Victims
- Don’t Protect Women

Without White Knights Feminism Would End Today

High Priority

Rich Women
Women
Rich Men
Girls
Boys
Animals
Prisoners
Men
Poor Men

Low Priority

They can get away with murder.
They get all the rights with no responsibility and Shelters for Homeless women.
They get bail out and short prison sentence.
They get educational benefits but no violence against kids Act.
They have some support but don’t have any education that fits boys.
They have animal rights and PETA.
They get conjugal visits and 3 squares and a roof.
Paid slaves.
Nothing.

Who pays the most Taxes?
This is why MGTOW exist.

Professor Subhashish Chattopadhyay
We must first understand the most important graph or image of Chemistry.

It is very strange, that so many Chemistry books exists in this world, which do not even have a single Periodic table in them. Almost all books do not have this graph either. This is the graph of electrode potential of various elements with respect to (standard) Hydrogen electrode.

All chemical reactions happen because of this electrode potential difference. When a solid is added to a solution of another compound such as a Gold Spoon in CuSO₄ Solution, or a Copper container having AgNO₃ Solution, then the displacement reaction happens or not is decided by these potential values. Battery and Electrochemistry chapter uses this knowledge. Oxidation-Reduction reactions, titrations etc all need this understanding.

The e.m.f of the standard cell Zn | Zn²⁺ || Ag⁺ | Ag \[ E^\circ_{\text{cell}} = 1.562 \text{ Volt} \]

If the standard electrode potential of Zinc is \( -0.762 \) Volt, then that of Silver is ?

Solution: \[ E^\circ_{\text{cell}} = E^\circ_{\text{Right}} - E^\circ_{\text{Left}} = E_{\text{Ag}^+ | \text{Ag}} - E_{\text{Zn}^2+ | \text{Zn}} = ( E_{\text{Reduction (Right)}} - E_{\text{Reduction (Left)}} ) \]
What will happen if a solution of copper sulphate put into an iron pot?

Note: Electrode potential of Cu is more positive (so higher) than Fe (Iron).

A solution of copper sulphate put into an iron pot will damage. This is because the standard electrode potential for Fe\(^{2+}\)/Fe is more negative than that for Cu\(^{2+}\)/Cu. The iron oxidises first, while copper ions are reduced. Iron will corrode (rust). Or in more simple words it is easier to replace Cu ions by Fe ions from the pot. Any element lower in the series tends to replace the element which is higher up the series.

This is called a redox reaction, since the iron is being oxidised, and copper ions reduced.

Note: A solution of Iron Salt in a Copper Vessel would have just done fine. In this case copper is in solid form, as vessel. So will not replace the Iron ions.
What will happen if a solution of Magnesium sulphate put into a Copper pot?

Note: Magnesium loses electron very easily, metallic character, or basic character being high. Electrode potential is - 2.37 While we know Copper has +ve electrode potential. (This is an important exception and the data is better remembered as 0.5)

So Copper is solid in Copper pot (or even if a copper spoon was inserted, the same logic). Copper will not replace Magnesium ions. But if a Magnesium spoon was put into Copper-Sulphate solution then the Magnesium ions/atoms will start replacing the Cu ions and Copper will start getting precipitated. The Magnesium spoon, or container will start getting corroded or damaged.
Nernst Equation also uses Electrode potential

Walther Hermann Nernst (1864 - 1941) German Physicist & Chemist received the Nobel prize in 1920 Chemistry.

\[
\begin{align*}
E_{cell} &= E_{cell}^0 - \frac{0.059}{n} \log \left( \frac{M^{n+}}{M^{n+}} \right) \\
E_{cell} &= E_{cell}^0 - \frac{0.059}{n} \log \left( \frac{M^{n+}}{M^{n+}} \right) \\
E_{cell} &= E_{cell}^0 - \frac{0.059}{n} \log \left( \frac{M^{n+}}{M^{n+}} \right)
\end{align*}
\]
Consider the following set of half-reactions

**Reduction**  \[ \text{Fe}^{2+} + 2e^- \overset{\text{red}}{\longrightarrow} \text{Fe} \quad E^\circ_{\text{red}} = -0.44 \text{ V} \]

**Oxidation**  \[ \text{Zn} \overset{\text{ox}}{\longrightarrow} \text{Zn}^{2+} + 2e^- \quad E^\circ_{\text{ox}} = +0.76 \text{ V} \]

**Overall**  \[ \text{Zn} + \text{Fe}^{2+} \overset{\text{cell}}{\longrightarrow} \text{Zn}^{2+} + \text{Fe} \quad E^\circ_{\text{cell}} = 0.32 \text{ V} \]

This is valid only if all species have concentrations of 1 \( M \).

Le Châtelier’s principle gives us some ideas. Look at the overall reaction. Consider the reaction to be at equilibrium (\( E_{\text{cell}} = 0 \text{ V} \)). If we add more \( \text{Fe}^{2+} \) to the reaction mixture, The equilibrium will shift to the right to use up the excess \( \text{Fe}^{2+} \). This will, of course cause a positive cell potential to be measurable.

Conversely, if we removed \( \text{Fe}^{2+} \) from the reaction mixture, the equilibrium would shift to the left to try to replace some of the missing \( \text{Fe}^{2+} \). This would result in a measurable negative potential (reaction goes left).

If the reaction were not at equilibrium then these preceding two changes would me additive to the measured voltage (say standard voltage). So, if we add \( \text{Fe}^{2+} \) to a mixture at Standard Conditions, then the voltage would be more positive and if we removed some \( \text{Fe}^{2+} \) from a mixture at Standard Conditions the measured voltage would be lower (less positive).

The reverse results would be found for addition or removal of \( \text{Zn}^{2+} \) (a product). More \( \text{Zn}^{2+} \) would give a lower positive potential and vice versa.

Recall the relation: \( \Delta G = \Delta G^\circ + RT \ln Q \) (for non-standard conditions)

Substitute the new definition of \( \Delta G \) and we get

\[-nFE = -nFE^\circ + RT \ln Q \]

\[ E - E^\circ = \frac{RT}{nF} \ln Q \] (This is called the Nernst Equation).

Thus, we can calculate the cell potential of any cell, given only the initial conditions (to calculate \( Q \)) and the reduction potentials (to calculate \( E^\circ \)).

We can calculate the voltage for the situation where the concentrations are not standard. For example, consider \([\text{Fe}^{2+}] = 0.1 \text{ M}\) and \([\text{Zn}^{2+}] = 1.9 \text{ M}\)

For this reaction, we also know that there are two electrons transferred for each equation (\( n = 2 \)).
Although the reaction is 90% complete (from Standard Conditions initial) the cell potential has only dropped by a small amount (0.04 V). This is normal. For example, the batteries in your flashlight will put out almost full voltage until the last traces of chemical are almost used up at which point the voltage will drop off rather sharply. This is an especially useful characteristic of cells powering electronic equipment.

A voltaic cell using inactive electrodes.

Oxidation half-reaction

\[ 2I^- (aq) \rightarrow I_2 (s) + 2e^- \]

Reduction half-reaction

\[ \text{MnO}_4^- (aq) + 8H^+ (aq) + 5e^- \rightarrow \text{Mn}^{2+} (aq) + 4H_2O(l) \]

Overall (cell) reaction

\[ 2\text{MnO}_4^- (aq) + 16H^+ (aq) + 10I^- (aq) \rightarrow 2\text{Mn}^{2+} (aq) + 5I_2 (s) + 8H_2O(l) \]

graphite \( I^- (aq) \parallel \text{I}_2 (s) \parallel \text{MnO}_4^- (aq), \text{H}^+ (aq), \text{Mn}^{2+} (aq) \parallel \text{graphite} \]

The inert electrode is specified. A comma is used to show components that are in the same phase.
A voltaic cell is made of aqueous Bromine and Zinc. Given -

\[ \text{Br}_2(aq) + \text{Zn}(s) \rightarrow \text{Zn}^{2+}(aq) + 2\text{Br}^{-}(aq) \quad E_{\text{cell}} = 1.83 \text{ V.} \]

Calculate \( E_{\text{bromine}} \), given that \( E_{\text{zinc}} = -0.76 \text{ V} \)

Solution:

\[ \begin{align*}
\text{Br}_2(aq) + 2e^- & \rightarrow 2\text{Br}^{-}(aq) & \text{[reduction; cathode]} \\
\text{Zn}(s) & \rightarrow \text{Zn}^{2+}(aq) + 2e^- & \text{[oxidation; anode]} \\
E_{\text{cell}} & = E_{\text{cathode}} - E_{\text{anode}} \\
1.83 & = E_{\text{bromine}} - (-0.76) \\
1.83 - 0.76 & = E_{\text{bromine}} = 1.07 \text{ Volt}
\end{align*} \]

What is the equilibrium constant for the reaction of copper metal with bromine to form copper(II) ions and bromide ions in aqueous solution at 25°C?

Cathode: \( \text{Br}_2 + 2e^- \rightleftharpoons 2\text{Br}^- \quad E_{\text{red}} = 1.09 \text{ V} \)

Anode: \( \text{Cu} \rightleftharpoons \text{Cu}^{2+} + 2e^- \quad E_{\text{ox}} = -E_{\text{red}} = -0.34 \text{ V} \)

Cell: \( \text{Cu} + \text{Br}_2 \rightleftharpoons \text{Cu}^{2+} + 2\text{Br}^- \quad E_{\text{cell}} = 0.75 \text{ V} \)

\[ \ln K = \frac{nFE_{\text{cell}}}{RT} = \frac{2 \times 96485 \cdot \frac{\text{C} \cdot \text{mol}}{\text{V} \cdot \text{mol}} \times 0.75 \text{ V}}{8.31451 \cdot \frac{\text{J}}{\text{mol} \cdot \text{K}} \times 298.15 \text{ K}} = 58.38 \times 10^{28} \]

\[ K = e^{58.38 \times 10^{28}} = 2.2 \times 10^{25} \]

Using half reactions write the spontaneous Redox reactions

\[ \begin{align*}
\text{Sn}^{2+}(aq) + 2e^- & \rightarrow \text{Sn}(s) \quad E_{\text{Sn}} = -0.14 \text{ V} \\
\text{Ag}^+(aq) + e^- & \rightarrow \text{Ag}(s) \quad E_{\text{silver}} = 0.80 \text{ V}
\end{align*} \]

We have to multiply the Silver reaction with 2 to balance and match electrons

Note: This does not change the voltage obtained

\[ 2\text{Ag}^+(aq) + 2e^- \rightarrow 2\text{Ag}(s) \quad E_{\text{silver}} = 0.80 \text{ V} \]
Now we need to add the half reactions to eliminate the electrons, but subtract to get the Voltage correctly. Recall $E_{\text{cell}} = E_{\text{Right}} - E_{\text{Left}} = E_{\text{Cathode}} - E_{\text{Anode}} = (E_{\text{Reduction (Right)}} - E_{\text{Reduction (Left)}})$

\[
\begin{align*}
\text{Sn(s)} & \rightarrow \text{Sn}^{2+}(aq) + 2e^- \\
2\text{Ag}^+(aq) + 2e^- & \rightarrow 2\text{Ag(s)} \\
\text{Sn(s)} + 2\text{Ag}^+(aq) & \rightarrow 2\text{Ag(s)} + \text{Sn}^{2+}(aq)
\end{align*}
\]

\[
E_{\text{cell}} = E_{\text{silver}} - E_{\text{Sn}} = 0.80 - (-0.14) = 0.94 \text{ V}
\]

Cathode provides electrons. Ag ions are receiving electrons at Cathode. Anode is positive where electrons are lost. See Tin is more metallic (than Silver) and is looses electrons in Anode.

It is easier to visualize the Voltage as gap in electrode potential. Silver is higher up than Hydrogen in the series. Thus has positive electrode potential. While Tin is more metallic, below Hydrogen in the series. The gap is of 0.94 Volts.

\[
E_{\text{cell}} = E_{\text{silver}} - E_{\text{Sn}} = 0.80 - (-0.14) = 0.94 \text{ V}
\]

- **Zinc and Magnesium Oxide Battery**

  \[
  \text{Anode (oxidation): } \quad \text{Zn(s)} + 2\text{OH}^-(aq) \rightarrow \text{ZnO(s)} + \text{H}_2\text{O(l)} + 2e^- \\
  \text{Cathode (reduction): } \quad \text{MnO}_2(s) + 2\text{H}_2\text{O(l)} + 2e^- \rightarrow \text{Mn(OH)}_2(s) + 2\text{OH}^-(aq) \\
  \text{Overall (cell) reaction: } \quad \text{Zn(s)} + \text{MnO}_2(s) + 2\text{H}_2\text{O(l)} \rightarrow \text{ZnO(s)} + \text{Mn(OH)}_2(s) \\
  E_{\text{cell}} = 1.5 \text{ V}
  \]

- **Zinc and Magnesium Oxide Battery**

  \[
  \text{Anode (oxidation): } \quad \text{Zn(s)} + 2\text{OH}^-(aq) \rightarrow \text{ZnO(s)} + \text{H}_2\text{O(l)} + 2e^- \\
  \text{Cathode (reduction): } \quad \text{Ag}_2\text{O(s)} + \text{H}_2\text{O(l)} + 2e^- \rightarrow 2\text{Ag(s)} + 2\text{OH}^-(aq) \\
  \text{Overall (cell) reaction: } \quad \text{Zn(s)} + \text{Ag}_2\text{O(s)} \rightarrow \text{ZnO(s)} + 2\text{Ag(s)} \\
  E_{\text{cell}} = 1.6 \text{ V}
  \]

The mercury battery uses HgO as the oxidizing agent instead of Ag$_2$O and has cell potential of 1.3 V.

- **The Lithium Batteries use Silver Vanadium Pentoxide as cathode**

  \[
  \text{Anode (oxidation): } \quad 3.5\text{Li(s)} \rightarrow 3.5\text{Li}^+ + 3.5e^- \\
  \text{Cathode (reduction): } \quad \text{AgV}_2\text{O}_5(s) + 3.5\text{Li}^+ + 3.5e^- \rightarrow \text{Li}_{3.5}\text{V}_2\text{O}_{5.5} \\
  \text{Overall (cell) reaction: } \quad \text{AgV}_2\text{O}_5(s) + 3.5\text{Li}(s) \rightarrow \text{Li}_{3.5}\text{V}_2\text{O}_{5.5}
  \]

CBSE Standard 12 Chemistry Survival Guide - Reduction Methods by Prof. Subhashish Chattopadhyay
SKMClasses Bangalore Useful for IIT-JEE, I.Sc. PU-II, Boards, IGCSE IB AP-Chemistry and other exams
The most commonly used Battery is Lead-Acid Battery

Anode (oxidation): \[ \text{Pb(s)} + \text{HSO}_4^-(aq) \rightarrow \text{PbSO}_4(s) + \text{H}^+(aq) + 2e^- \]
Cathode (reduction):
\[ \text{PbO}_2(s) + 3\text{H}^+(aq) + \text{HSO}_4^-(aq) + 2e^- \rightarrow \text{PbSO}_4(s) + 2\text{H}_2\text{O}(l) \]
Overall (cell) reaction (discharge):
\[ \text{PbO}_2(s) + \text{Pb(s)} + \text{H}_2\text{SO}_4(aq) \rightarrow 2\text{PbSO}_4(s) + 2\text{H}_2\text{O}(l) \quad E_{\text{cell}} = 2.1 \text{ V} \]
Overall (cell) reaction (recharge):
\[ 2\text{PbSO}_4(s) + 2\text{H}_2\text{O}(l) \rightarrow \text{PbO}_2(s) + \text{Pb(s)} + \text{H}_2\text{SO}_4(aq) \]

Nickel Metal Hydride Battery

Anode (oxidation):
\[ \text{MH(s)} + \text{OH}^-(aq) \rightarrow \text{M(s)} + \text{H}_2\text{O}(l) + e^- \]
Cathode (reduction):
\[ \text{NiO(OH)}(s) + \text{H}_2\text{O}(l) + e^- \rightarrow \text{Ni(OH)}_2(s) + \text{OH}^-(aq) \]
Overall (cell) reaction:
\[ \text{MH(s)} + \text{NiO(OH)}(s) \rightarrow \text{M(s)} + \text{Ni(OH)}_2(s) \quad E_{\text{cell}} = 1.4 \text{ V} \]

Laptops, Cell-phones most commonly use Lithium ion Batteries

Anode (oxidation):
\[ \text{Li}_x\text{C}_{6}(s) \rightarrow x\text{Li}^+ + xe^- + \text{C}_{6}(s) \]
Cathode (reduction):
\[ \text{Li}_x\text{Mn}_2\text{O}_4(s) + x\text{Li}^+ + xe^- \rightarrow \text{LiMn}_2\text{O}_4(s) \]
Overall (cell) reaction:
\[ \text{Li}_x\text{C}_{6}(s) + \text{Li}_x\text{Mn}_2\text{O}_4(s) \rightarrow \text{LiMn}_2\text{O}_4(s) \quad E_{\text{cell}} = 3.7 \text{ V} \]

Hydrogen Fuel Cell

Anode (oxidation):
\[ 2\text{H}_2(g) \rightarrow 4\text{H}^+(aq) + 4e^- \]
Cathode (reduction):
\[ \text{O}_2(g) + 4\text{H}^+(aq) + 4e^- \rightarrow 2\text{H}_2\text{O}(g) \]
Overall (cell) reaction:
\[ 2\text{H}_2(g) + \text{O}_2(g) \rightarrow 2\text{H}_2\text{O}(g) \quad E_{\text{cell}} = 1.2 \text{ V} \]
What is the value of the solubility product constant for AgCl?

We could calculate this by breaking the overall $K_{sp}$ reaction into a series of redox reactions as follows:

Anode: $\text{Ag(s) \rightarrow Ag}^{+} + e^{-}$ $E_{\text{ox}} = -0.80$ V

Cathode: $\text{AgCl} + e^{-} \rightarrow \text{Ag(s)} + \text{Cl}^{-}$ $E_{\text{red}} = 0.22$ V

Overall (° $K_{sp}$ reaction) $\text{AgCl} \rightarrow \text{Ag}^{+} + \text{Cl}^{-}$ $E_{\text{cell}} = -0.58$ V (not very spontaneous)

$$\ln K = \frac{nFE^{\circ}}{RT} = \frac{1 \times 96485 \text{ C mol}^{-1} \text{ mol} (0.58 \text{ V})}{8.3145 \text{ J mol}^{-1} \text{ K}^{-1} \times 298.15 \text{ K}} = 22.5744$$

$K = 6.3 \times 10^{-9}$

Ion Concentrations can also be calculated...

Consider the Platinum-Hydrogen electrode coupled with a copper/copper(II) electrode.

The overall reaction is $\text{Cu}^{2+} + \text{H}_2 \rightarrow \text{Cu} + 2\text{H}^{+}$.

The Nernst equation is

$$E = E^{\circ} - \frac{0.0257 \text{ V}}{2} \ln \left( \frac{a(\text{H}^{+})^2}{a(\text{Cu}^{2+}) \times a(\text{H}_2)} \right)$$

Since

$$\frac{8.31451 \text{ J mol}^{-1} \text{ K}^{-1} \times 298.15 \text{ K}}{96485 \text{ C mol}^{-1}} = 0.0258_{\text{gas}} \text{ V}$$

If $[\text{Cu}^{2+}] = 1 \text{ M}$ and $P(\text{H}_2) = 1 \text{ bar}$ (both their activities are 1) then

$$E = E^{\circ} - \frac{0.0257 \text{ V}}{2} \ln [\text{H}^{+}]$$

(Note: $\ln Y = 2.303 \times \log Y$ and $-0.257 \times 2.303 = 0.05917$)

$$E = E^{\circ} + 0.05917 \text{ V (-log [H]^{+})}$$
We see here that the cell potential is a function of pH. The probes in pH meters are set up this way. A complete electrochemical cell is contained within the probe casing. All chemicals are at standard conditions and a porous glass membrane allows only $H^+$ ions to pass through.

**Electrochemical Cell**

The electrochemical cell shown below is a concentration cell.

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Reduction Methods in Organic Chemistry

Let us always remember the basics. If something, say M, loses electrons, it is getting oxidized. Metals are basic. Metals lose electrons and get oxidized. The metals which lose electron very easily, get oxidized very easily. So these are better reducing agents.

Adding of Oxygen, or Halogens (F, Cl, Br, I) or other p-Block elements which accept electrons, is oxidation. So if Potassium (K) gets Oxygen (attaches to O) to form K₂O or KO₂ (Superoxide), K is getting oxidized. If Cs attaches with F then Cs is getting oxidized, while F is being reduced. Cs is a reducing agent as it is loosing electrons. F is an oxidizing agent as it is gaining electrons.

Adding of Hydrogen is reduction. So if Ethene receives Hydrogen to become Ethane, then Ethene is being reduced. Raney Nickel is Nickel with molecular level pores. Raney Ni with HCl gives Hydrogen atoms, (some teachers say this as Nascent Hydrogen) locally, meaning near the molecule where the reaction is needed. So Raney Ni + HCl is a good reducing agent. Same for Zinc dust + HCl. But then what is Birch reduction?

As my experience of teaching more than 25 years, almost every student understands these. Knowing this is essential but does not ensure success in Organic chemistry. There are many kinds of details of oxidizing agent or Reducing agent that vary from reactions / situations.

I reasonably searched and realized that details of Oxidation or Reduction is scattered. There is no single e-Book that gives all of these as a collection.

So this e-Book is free for you. All information at a single place.

Gilman’s Reagent (An organometallic compound)

Br or Oxygen atoms were being knocked out. Removal of Oxygen or halogen is reduction.
Adding nascent hydrogen is Reduction.

\[ \text{CH}_2\text{C} = \text{N} \xrightarrow{\text{SnCl}_2/\text{HCl}} \text{[CH}_3\text{CH} = \text{NH} \cdot \text{HCl]} \xrightarrow{\text{H}_2\text{O}/\Delta} \text{CH}_3\text{CHO} + \text{NH}_4\text{Cl} \]

RMgI is Grignard reagent. R always becomes Anion, i.e. negatively charged ion. MgI is cation, i.e. positively charged. With water OH group joins Mg.

\[ \text{CH}_2\text{C} = \text{N} \xrightarrow{\text{RMgI}} \text{CH}_3\text{C} = \text{N MgI} \xrightarrow{\text{H}_2\text{O}} \text{CH}_3\text{C} = \text{O} + \text{NH}_3 + \text{Mg(OH)}\text{I} \]

\[ \text{NaBH}_4 \] is a strong reducing agent. Aldehyde in this case reduces to alcohol.

\[ \text{CH}_2\text{CH} = \text{CHO} \xrightarrow{\text{NaBH}_4} \text{CH}_2\text{CH} = \text{CHCH}_2\text{OH} \]

Preparation of ethanal from carbon and hydrogen can be effected by following reaction:

\[ 2\text{C} + \text{H}_2 \xrightarrow{\text{Electric arc \ 3000 K}} \text{CH} = \text{CH} \xrightarrow{\text{H}_2\text{SO}_4/\text{H}_2\text{O} \ \text{H}_2\text{SO}_4} \text{CH}_3\text{CHO} \]

The carbonyl group (\(\text{C} = \text{O}\)) can be reduced to methylenic group (\(\text{CH}_2\)) resulting in the formation of alkanes by any of the following reagents:

(i) \(\text{Zn-Hg/HCl}\) : Claiemensen's reduction
(ii) \(\text{H}_2\text{N-NH}_2/\text{KOH}\) : Wolff Kishner's reduction
(iii) \(\text{HI/P at 424 K}\)

This was an industrial way of adding hydrogen. (thus reduction).
Trimethyl silyl iodide:

\[
\begin{align*}
\text{Ph} & \xrightarrow{\text{Me}_3\text{Si-I}} \text{Ph-OH} + I \\
\text{Cyclohexanone} & \xrightarrow{\text{Me}_3\text{Si-I}} \text{Cyclohexanone-OH} + I \\
\text{Benzene} & \xrightarrow{\text{Me}_3\text{Si-I}} \text{Ph-OH} + I
\end{align*}
\]

Peterson's synthesis: Beta hydroxyl Trimethyl silane

\[
\text{Carbonyl compounds} \xrightarrow{\text{SiMe}_3\text{Base/THF}} \text{Olefins}
\]

\[
\begin{align*}
\text{Ph} & \xrightarrow{\text{H}_2/\text{Ni}} \text{Ph} \\
\text{Benzene-COOH} & \xrightarrow{\text{H}_2/\text{N}/\text{High pressure}} \text{Benzene-COOH}
\end{align*}
\]

Baker's yeast:

\[
\begin{align*}
\text{Acetic acid} & \xrightarrow{} \text{Ethanol + Acetaldehyde}
\end{align*}
\]
Wolf Kishner reduction (Knocking out Oxygen)

Wolf kishner reduction ($\text{H}_2\text{N-NH}_2/\text{KOH}$)

LDA (Lithium di isopropyl amide):
Strong base due to $^2\text{O}$ amine & free e' pair. Satirically hindered base

Wilkinson’s catalyst (Tris (tri phenyl phosphine)rhodium(I) chloride):
Hydrogenation of $\equiv\text{C-C}=\text{C}$, with out disturbing other functional groups.
It adds $\text{H}_2$ to alkenes at same side, Cis olefin to meso, Trans olefin to racemic mixture.

Pi bonds were being broken and hydrogen atoms were being added.
Birch Reduction is the only way to break the double bonds of Benzene and convert to cyclohexane. Benzene ring is pretty stable, and known as resonance stabilization. Adding hydrogen (i.e. reduction) of benzene is not easy.

Metal surface catalysts (Palladium in this case) gives cis isomer. This is because an intermediate is formed where both sides join the metal surface. Both sides being towards the metal catalyst eventually makes it cis.
Clemmenson’s reduction is Zn / Hg with HCl

Clemmenson’s (Zn-Hg/HCl):

\[ \text{Clemmenson's reduction is Zn} / \text{Hg with HCl} \]

Alanes (AlH₃):

With silanes:

Reduction with HCO₂H:

Sodium boro hydride:
Reduces predominately unconjugated carbonyl compounds

Vils meier reaction:

Silver tetra fluoro borate (AgBF₄):

\[ \text{Silver tetra fluoro borate (AgBF}_4\text{)} \]

\[ \text{Vils meier reaction} \]

\[ \text{Clemmenson's (Zn-Hg/HCl):} \]

\[ \text{Alanes (AlH}_3\text{)}: \]

\[ \text{With silanes:} \]

\[ \text{Reduction with HCO}_2\text{H/Heat} \]

\[ \text{Sodium boro hydride:} \]

\[ \text{Reduces predominately unconjugated carbonyl compounds} \]

\[ \text{Vils meier reaction} \]

\[ \text{Silver tetra fluoro borate (AgBF}_4\text{)}: \]
Luche's reagent (NaBH₄·CeCl₃): Reducing conjugating carbonyl compounds, reduces ketones more efficiently than aldehydes.

Super hydride (LiBH₄):  

Sodium cyano boro hydride (NaBH₃CN):  
Readily reduces iodides, bromides, and tosylates to the hydrocarbons...  
HMPA = hexa methyl phosphoramide

Ketones reacts with Grignard reagents giving tertiary alcohols.

Example:

CH₃CH₂MgBr + H₂C-CH₂CH₃  

DIBAL-H (Di is o butyl aluminium hydride):  
High temperatures: Acid derivatives to Alcohols  
Low temperatures: Acid derivatives to Aldehydes

X=OMe, NH₂ etc
Adams catalyst ($H_2$-PtO$_2$): Less hindered alkenes to alkanes.

Rosenmund reduction:

$$R-\text{Cl} \stackrel{Pd-BaSO_4, H_2}{\rightarrow} R-\text{H}$$

Grignard reactions of carbonyl compounds

Formaldehyde ($H_2C=O$) reacts with Grignard reagents giving primary alcohol.

$$R-MgX + H_2C=O \rightarrow H-C-O^- + MgX \rightarrow R-CH_2-OH$$

or

$$R-MgX + H_2C=O \rightarrow H-C-O^- + MgX \rightarrow R-CH_2-OH$$

Example:

$$\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{MgBr} + H_2C=O \rightarrow \text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{OH}$$

(1-pentanol 92%) butylimagnesium bromide

Aldehydes react with Grignard reagents giving secondary alcohols.

$$R-MgX + H-C=O \rightarrow H-C-O^- + MgX \rightarrow R-C-OH$$

or

$$R-MgX + H-C=O \rightarrow H-C-O^- + MgX \rightarrow R-C-OH$$

Example:

$$\text{CH}_3\text{CH}_2\text{MgBr} + H_2C=O \rightarrow \text{CH}_3\text{CH}_2\text{C}-\text{OH}$$
NaNH₂ is a strong base and excellent nucleophile. It’s used for deprotonation of weak acids and also for elimination reactions. Similar to: LDA (lithium diisopropylamide). The bases LiNH₂ and KNH₂ essentially similar. As a strong base, NaNH₂ will deprotonate alkynes, alcohols, and a host of other functional groups with acidic protons such as esters and ketones. It is also a very strong nucleophile. One common application of NaNH₂ is in the deprotonation of alkynes to give so-called “acetylide” ions. These ions are excellent nucleophiles and can go on to react with carbonyls in addition reactions.

Deprotonation of alkynes

A second application of NaNH₂ is in the formation of alkynes from halogens. Treatment of either geminal dihalides (i.e. - two halogens on one carbon) or vicinal dihalides (halogens on adjacent carbons) with NaNH₂ (2 equiv) will result in the formation of alkynes. So this is reducing property.
Since vicinal dihalides are easily made by the reaction of alkenes with halogens such as Br₂ or I₂, this is a useful way of converting alkenes to alkynes.

Deprotonation of functional groups such as OH and even alkyne C-H should hopefully be straightforward, but the use of bases to make alkenes may require some explanation. This is what is known as an elimination reaction, in that the elements H and Br (in this example) are removed in order to form the alkene. Specifically, this is an example of an E2 reaction.

\[
\begin{align*}
C_3H_7-\equiv\equivC-H & \xrightarrow{1. Na\text{NH}_2} C_3H_7-\equiv\equivC-C_2H_5 \\
& \xrightarrow{2. C_2H_5Br} \text{Na\text{NH}_2} \\
& \xrightarrow{H_2O^+} C_3H_7-\equiv\equivC-H \\
& \text{1-hexyne}
\end{align*}
\]

Since the alkene still has a halide attached, this too can be removed to generate a second double bond (π bond). This is another example of the E2 in that the hydrogen has to be anti to the bromine that is eliminated, but is unusual in that it is an sp² hydrogen that is affected here:

\[
\begin{align*}
\text{NaNH}_2 & \text{can replace Chlorine} \\
\text{Conversion of acyl halides to amides}
\end{align*}
\]

Furthermore, since NaNH₂ is a strong base, it has the significant disadvantage of promoting side reactions from elimination (this can occur when attempting an SN2 with NaNH₂ as the nucleophile, for example). Therefore, it is generally wise to avoid using NaNH₂ as a nucleophile in organic synthesis. Sodium azide (followed by reduction) is the usual substitute.
NaNH₂ acts as reducing agent.
Benzyne Reaction: Elimination-Addition

$\begin{align*}
\text{Br} & \xrightarrow{\text{Na}^+ \cdot \text{NH}_3, -33^\circ\text{C}} \text{NH}_2 \\
\text{CH}_3 & \quad \text{CH}_3
\end{align*}$

$p$-bromotoluene

$\text{p-toluidine (50\%)} + \text{m-toluidine (50\%)}$

Reactant is halobenzene with no electron-withdrawing groups on the ring.
Use a very strong base like $\text{NaNH}_2$.

Another reaction done in cold

$\begin{align*}
\text{Cl} & \xrightarrow{\text{NaNH}_2, \text{NH}_3, -33^\circ\text{C}} \text{NH}_2 \\
\text{Cl} & \quad \text{N}
\end{align*}$
Topic wise grouping of information kind of Dictionary of General Chemistry

Graphite and Diamond comparison

With respect to graphite and diamond, which of the following statement(s) given below is(are) correct?
(a) Graphite is harder than diamond.
(b) Graphite has higher electrical conductivity than diamond.
(c) Graphite has higher thermal conductivity than diamond.
(d) Graphite has higher C—C bond order than diamond.

Solution:
The given facts about graphite and diamond are as follows.
Graphite is less hard than diamond. Graphite has higher electrical and thermal conductivities than diamond. This is due to highly delocalized nature of \( \pi \) electrons. Graphite has higher C—C bond order (due to \( \sigma \) and \( \pi \) bonds) than that of diamond (which has only \( \sigma \) bonds).
Therefore, the choices (b), (c) and (d) are correct.

Stability of lyophobic colloidal particles

Choose the correct reason(s) for the stability of lyophobic colloidal particles.
(a) Preferential adsorption of ions on their surface from the solution.
(b) Preferential adsorption of solvent on their surface from the solution.
(c) Attraction between different particles having opposite charges on their surface.
(d) Potential difference between the fixed layer and the diffused layer of opposite charges around the colloidal particles.

Solution:
The stability of lyophobic colloidal particles is due to the preferential adsorption of common ion from the solution. Each colloidal particle has the same charge and are thus kept away from each other due to electronic repulsion (choice a).
There exists potential difference between the fixed and diffused layer of opposite charge (choice d).
Therefore, the choice (a) and (d) are correct.

Physiorption and Chemisorption comparison

The given graph/data I, II, III and IV represent general trends observed for different physisorption and chemisorption processes under mild conditions of temperature and pressure. Which of the following choice(s) about I, II, III and IV is(are) correct.

![Graph I](image1)

![Graph II](image2)
(a) I is physisorption and II is chemisorption
(c) IV is chemisorption and II is chemisorption
(b) I is physisorption and III is chemisorption
(d) IV is chemisorption and III is chemisorption

**Solution:**

We have the following facts:

- Adsorption decreases with increase in temperature at constant pressure in case of physisorption.
- Adsorption increases initially with increase in temperature at constant pressure in case of chemisorption as more molecules satisfy the energy of activation.
- The enthalpy change during chemisorptions is high due to the bond formation between adsorbent and adsorbate.

With these guidelines, we will have:

Graph I represents physisorption
Graph III represents physisorption

Graph II represents chemisorption
Graph IV represents chemisorptions

Therefore, The choices *(a)* and *(c)* are correct.

---

A compound \( M_nX_q \) has cubic close packing (CCP) arrangement of X. Its unit cell structure is shown below.

The empirical formula of the compound is

(a) \( MX \)  
(b) \( MX_2 \)  
(c) \( M_2X \)  
(d) \( M_3X_{14} \)

**Solution:**

The atom at the corner of the cube is shared amongst 8 unit cells; the atom at the centre of a face is shared between 2 unit cells, the atom at the centre of edges is shared amongst 4 unit cells and that at the centre of the cube belongs wholly to the unit cell.

There are eight \( X \) atoms at the corners and six \( X \) atoms at the centre of faces. Thus, the number of \( X \) atoms per
unit cell is

$$8 \left( \frac{1}{8} \right) + 6 \left( \frac{1}{2} \right) = 1 + 3 = 4$$

There are four M atoms at the centre of edges and one M atom at the centre of the cube. Thus, the number of M atoms per unit cell is

$$4 \left( \frac{1}{4} \right) + 1(1) = 1 + 1 = 2$$

The formula of the compound will be $M_2X_4$ and the empirical formula will be $MX_2$. Therefore, the choice (b) is correct.

HCl, HBr and HI react with AgNO₃ to give a precipitate that dissolves in Na₂S₂O₃.

Which of the following halides react with AgNO₃ to give a precipitate that dissolves in Na₂S₂O₃ (aq)?

(a) HCl  
(b) HF  
(c) HBr  
(d) HI

**Solution:**

The precipitates of AgCl, AgBr and AgI are soluble in Na₂S₂O₃ (aq) forming the complex Na₃[Ag(S₂O₃)₂]. For example,

$$Na_2S_2O_3 + 2AgBr \rightarrow Ag_2S_2O_3 + 2NaBr$$
$$Ag_2S_2O_3 + 3Na_2S_2O_3 \rightarrow 2Na_3[Ag(S_2O_3)_2]$$

AgF is soluble in water. Therefore, the choices (a), (c) and (d) are correct.

Reversible expansion of an ideal gas

The reversible expansion of an ideal gas under adiabatic and isothermal conditions is shown in the figure. Which of the following statement(s) is(are) correct?

(a) $T_1 = T_2$  
(b) $T_2 > T_1$  
(c) $w_{\text{isothermal}} > w_{\text{adiabatic}}$  
(d) $\Delta U_{\text{isothermal}} > \Delta U_{\text{adiabatic}}$

**Solution:**

We will have $T_1 = T_2$ as the expansion is isothermal. $T_2 < T_1$ as the adiabatic expansion involves cooling.

$w_{\text{isothermal}} > w_{\text{adiabatic}}$ as the area under the isothermal curve is greater than that under adiabatic curve.

$\Delta U_{\text{isothermal}} = 0$ as temperature remains constant while $\Delta U_{\text{adiabatic}} < 0$ as the expansion occurs at the expanse of internal energy.

Therefore, the choices (a) and (d) are correct.

**Note:** The choice (c) is correct if the magnitude of the work is considered. Since expansion carries negative sign as per IUPAC recommendations, the choice (c) will not be correct if the negative sign is also considered.
Acid Ionization Constant

\[ K_a = \frac{[H^+][A^-]}{[HA]} \]

Adiabatic change

\[ PV = k \]

Base Ionization Constant

\[ K_b = \frac{[OH^-][HB^+]}{[B]} \]

Bohr Radius

\[ a_0 = \frac{\hbar^2}{m_e k c^2} \]

Boiling Point Elevation

\[ \Delta T_b = i K_b \times molality \]

Buffer Design Equation

\[ pH \approx pK_a - \log \left( \frac{[HA]_0}{[A^-]_0} \right) \]

Cell Voltage

\[ E_{cell} = E_{cell}^\circ - \frac{RT}{n F} \ln Q = E_{cell}^\circ - \frac{0.0592}{n} \log Q \]

Charles' Law

\[ \frac{V}{t} = k \]

**Atomic Structure**

### DESCRIPTION | EQUATION
--- | ---
Bohr Radius | \[ a_0 = \frac{\hbar^2}{m_e k c^2} \]
De Broglie Wavelength | \[ \lambda = \frac{\hbar}{mv} \]
Linear Momentum | \[ p = mv \]
Planck's Quantized (Quantum) Energy Equation | \[ \Delta E = h \nu \]
Radii of stable orbits in the Bohr model | \[ r = n^2 \frac{\hbar^2}{m_e k Z c^2} = n^2 a_0 \frac{a_0}{Z} \]
Relationship between Energy and Principal Quantum Number | \[ E_n = -R_H \left( \frac{1}{n^2} \right) = -2.178 \times 10^{-18} \text{ joule} \]
Rydberg Equation
$$\Delta E = R_H \left( \frac{1}{n_i^2} - \frac{1}{n_f^2} \right)$$

Speed of Light to Wavelength and Frequency Relationship
$$c = \lambda \nu$$

**Electrochemistry**

<table>
<thead>
<tr>
<th>DESCRIPTION</th>
<th>EQUATION</th>
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</thead>
<tbody>
<tr>
<td>Cell Voltage</td>
<td>$E_{cell} = E_{cell}^o - \frac{RT}{nF} \ln Q = E_{cell}^o - \frac{0.0592}{n} \log Q$</td>
</tr>
<tr>
<td>Electric Current</td>
<td>$I = \frac{q}{t}$</td>
</tr>
<tr>
<td>Reaction Quotient</td>
<td>$Q = \frac{[C]^c[D]^d}{[A]^a[B]^b}$ where $aA + bB \rightarrow cC + dD$</td>
</tr>
<tr>
<td>Relationship between Equilibrium Constant and Cell Voltage</td>
<td>$\log K = \frac{nE^o}{0.0592}$</td>
</tr>
</tbody>
</table>

**Equilibrium**

<table>
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<tr>
<th>DESCRIPTION</th>
<th>EQUATION</th>
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<tbody>
<tr>
<td>Acid Ionization Constant</td>
<td>$K_a = \frac{[H^+][A^-]}{[HA]}$</td>
</tr>
<tr>
<td>Base Ionization Constant</td>
<td>$K_b = \frac{[OH^-][HB^+]}{[B]}$</td>
</tr>
<tr>
<td>Buffer Design Equation</td>
<td>$pH \approx pK_a - \log \frac{[HA]_0}{[A^-]_0}$</td>
</tr>
<tr>
<td>Gas Pressure and Concentration Relationship</td>
<td>$K_p = K_c (RT)^\Delta n$</td>
</tr>
<tr>
<td>Ion Product Constant for Water</td>
<td>$K_w = [OH^-][H^+] = K_a \times K_b = 1.0 \times 10^{-14}$ at $25^\circ C$</td>
</tr>
<tr>
<td>pH and pOH Relationship</td>
<td>$14 = pH + pOH$</td>
</tr>
<tr>
<td>pH Defined</td>
<td>$pH = -\log [H^+]$</td>
</tr>
<tr>
<td>pKₐ Definition</td>
<td>$pK_a = -\log K_a$</td>
</tr>
</tbody>
</table>
pK_b Definition

\[ pK_b = -\log K_b \]

pOH and Base Ionization Equilibrium Constant Relationship

\[ pOH = pK_b + \log \frac{[HB^+]}{[B]} \]

**Gases, Liquids, and Solutions**

<table>
<thead>
<tr>
<th>DESCRIPTION</th>
<th>EQUATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adiabatic change</td>
<td>[ PV = k ]</td>
</tr>
<tr>
<td>Boiling Point Elevation</td>
<td>[ \Delta T_b = iK_b \times \text{molality} ]</td>
</tr>
<tr>
<td>Charles' Law</td>
<td>[ \frac{V}{t} = k ]</td>
</tr>
<tr>
<td>Combined Gas Law</td>
<td>[ \frac{P_1V_1}{n_1T_1} = \frac{P_2V_2}{n_2T_2} ]</td>
</tr>
<tr>
<td>Density of a Material</td>
<td>[ D = \frac{m}{V} ]</td>
</tr>
<tr>
<td>Freezing Point Depression</td>
<td>[ \Delta T_f = iK_f \times \text{molality} ]</td>
</tr>
<tr>
<td>Graham's Law of Effusion</td>
<td>[ \frac{r_1}{r_2} = \sqrt{\frac{M_2}{M_1}} ]</td>
</tr>
<tr>
<td>Ideal gas equation</td>
<td>[ PV = nRT ]</td>
</tr>
<tr>
<td>Kinetic Energy per Mole</td>
<td>[ \frac{KE}{mole} = \frac{3}{2}RTn ]</td>
</tr>
<tr>
<td>Kinetic Energy per Mole</td>
<td>[ \frac{KE}{mole} = \frac{3}{2}RTn ]</td>
</tr>
</tbody>
</table>

**Thermochemistry**

<table>
<thead>
<tr>
<th>DESCRIPTION</th>
<th>EQUATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acid Ionization Constant</td>
<td>[ K_a = \frac{[H^+][A^-]}{[HA]} ]</td>
</tr>
<tr>
<td>Adiabatic change</td>
<td>[ PV = k ]</td>
</tr>
<tr>
<td>Base Ionization Constant</td>
<td>[ K_b = \frac{[OH^-][HB^+]}{[B]} ]</td>
</tr>
</tbody>
</table>
Bohr Radius

\[ a_0 = \frac{\hbar^2}{m_e k e^2} \]

Boiling Point Elevation

\[ \Delta T_b = i K_b \times \text{molality} \]

Buffer Design Equation

\[ pH \approx pK_a - \log \frac{[HA]_0}{[A^-]_0} \]

Cell Voltage

\[ E_{cell} = E_{cell}^0 - \frac{RT}{nF} \ln Q = E_{cell}^\circ - \frac{0.0592}{n} \log Q \]

Charles' Law

\[ \frac{V}{t} = k \]

Vander waal's force

For one mole of a van der Waals gas when \( b = 0 \) and \( T = 300 \text{ K} \), the plot of \( pV \) versus \( 1/V \) is shown below.

The value of the van der Waals constant \( a \) is
(a) 1.0 L^2 atm mol^{-2}  (b) 4.5 L^2 atm mol^{-2}  (c) 1.5 L^2 atm mol^{-2}  (d) 3.0 L^2 atm mol^{-2}

**Solution:**

For one mole of a gas, the van der Waals equation is

\[ (p + \frac{a}{V^2})(V - b) = RT \]

When \( b = 0 \), we have

\[ \left( p + \frac{a}{V^2} \right) V = RT \quad \text{i.e.} \quad pV = RT - \frac{a}{V} \]

The plot of \( pV \) versus \( 1/V \) will be a straight line with slope equal to \(-a\). Hence

Slope of the given straight line is

\[ \frac{(20.1 - 21.6) \text{L atm mol}^{-1}}{(3.0 - 2.0) \text{molL}^{-1}} = -1.5 \text{ L}^2 \text{ atm mol}^{-2} \]

Equating this to \(-a\), we get

\[ a = 1.5 \text{ L}^2 \text{ atm mol}^{-2} \]

Therefore, the choice (c) is correct.

dilute solution containing 2.5 gm of nonvolatile
For a dilute solution containing 2.5 g of a non-volatile non-electrolyte solute in 100 g of water, the elevation of boiling point at 1 atm pressure is 2 °C. Assuming concentration of solute is much lower than the concentration of solvent, the vapour pressure of the solution (take \( K_b = 0.76 \text{ K kg mol}^{-1} \)) is
(a) 724 mmHg (b) 740 mmHg (c) 736 mmHg (d) 718 mmHg

**Solution:**

From the expression \( \Delta T_b = K_b m \), we find that the molality of solute (\( m \)) in the solution is

\[
m = \frac{\Delta T_b}{K_b} = \frac{2}{0.76 \text{ K kg mol}^{-1}} = \frac{2}{0.76} \text{ mol kg}^{-1}
\]

Since \( m = \frac{n_2}{m_1} \) (where \( n_2 \) is the amount of solute and \( m_1 \) is the mass of solvent expressed in kg), we get:

\[
n_2 = mm_1 = \left( \frac{2}{0.76} \text{ mol kg}^{-1} \right) (0.1 \text{ kg}) = \frac{2}{7.6} \text{ mol}
\]

From the expression \( -\Delta P = x_2 P^* \) of the relative lowering of vapour pressure of solvent (whose vapour pressure is 1 atm as the solute is non-volatile), we find that

\[
x_2 = \frac{n_2}{n_1 + n_2} \frac{n_2}{n_1} = \frac{n_2}{m_1/M_1} = \frac{(2/7.6) \text{ mol}}{(100 \text{ g}/18 \text{ g mol}^{-1})} = \frac{36}{76}
\]

Hence \( -\Delta P = \left( \frac{36}{760} \right) (760 \text{ mmHg}) = 36 \text{ mmHg} \)

\[p - p^* + \Delta P = 760 \text{ mmHg} - 36 \text{ mmHg} = 724 \text{ mmHg}\]

Therefore, the choice (a) is correct.

The shape of XeO2F2 molecule is seesaw

The shape of XeO2F2 molecule is
(a) trigonal bipyramidal (b) square planar (c) tetrahedral (d) see-saw

**Solution:**

The number of valence electrons in XeO2F2 is \( 8 + 2 \times 6 + 2 \times 7 = 34 \). These are distributed as shown in the following.

There are five pairs of electrons around Xe. To accommodate these, Xe undergoes dsp³ hybridization leading to the trigonal bipyramidal arrangement of five pairs of electrons. The structure of XeO2F2 is

The shape of XeO2F2 is sea-saw.

Therefore, the choice (d) is correct.
Various Increasing and Decreasing properties

Decreasing order of reactivity towards $S_{N2}$ displacement:
- $n$-Butyl bromide, isobutyl bromide, sec-butyl bromide, tert-butyl bromide

Increasing order of reactivity towards $S_{N1}$ displacement:
- 1-bromopentane, 2-bromopentane, 2-bromo-2-methylbutane

Increasing reactivity sequence of $S_{N1}$ displacement of halogen: $CH_3X$, $1^o X$, $2^o X$, $3^o X$.

Increasing reactivity sequence of $S_{N2}$ displacement of halogen: $CH_3X$, $1^o X$, $2^o X$, $3^o X$.

Increasing reactivity of alcohols towards gaseous HBr:
- 2-butanol, 2-methyl-1-propanol, 2-methyl-2-propanol

Increasing order or reactivity towards E2 dehydrohalogenation of the bromides:
- ethyl bromide, $n$-proyl bromide, isobutyl bromide, neopentyl bromide

Increasing stability of alkenes: $R_2C=CR_2$, $R_2C=CHR$, $R_2C=CH_2$, $RCH=CH_2$, $CH_2=CH_2$

Increasing dehydration of alcohol in the presence of $H_2SO_4$:
- ethyl alcohol, isopropyl alcohol, tert-butyl alcohol

Decreasing order of reactivity towards E2 dehydrohalogenation:
- 2-bromo-2-methylbutane, 1-bromopentane, 2-bromopentane, 3-bromopentane

Increasing order of dehydrohalogenation:
- 1-bromo-3-methylbutane, 2-bromo-2-methylbutane, 3-bromo-2-methylbutane

calculate multiple bond energy of a C triple bond

Using the data provided, calculate the multiple bond energy of a $C\equiv C$ bond in $C_2H_2$.

\[
2C(s) + H_2(g) \rightarrow C_2H_2(g) \quad \Delta H_1 = 225 \text{ kJ mol}^{-1}
\]

\[
2C(s) \rightarrow 2C(g) \quad \Delta H_2 = 1410 \text{ kJ mol}^{-1}
\]

\[
H_2(g) \rightarrow 2H(g) \quad \Delta H_3 = 330 \text{ kJ mol}^{-1}
\]

Take the bond energy of $C-H$ bond equal to 350 kJ mol$^{-1}$.

(a) 1165 kJ mol$^{-1}$ \quad (b) 837 kJ mol$^{-1}$ \quad (c) 865 kJ mol$^{-1}$ \quad (d) 815 kJ mol$^{-1}$

**Solution:**

Consider the following transformations.

\[
\begin{align*}
2C(s) + H_2(g) & \quad \Delta H_1 \\
\Delta H_2 & \quad \Delta H_3 \\
2C(g) + 2H(g) & \rightarrow C_2H_2(g)
\end{align*}
\]

\[
\begin{align*}
& \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \ Quad
Largest Anion - $\text{At}^-$

Metals having highest b.pt and m.pt. = mercury and tungsten

Most reactive solid element - Li

Most reactive liquid element - Cs

total no. of gaseous element in periodic table - 11 ($H, He, N, O, F, Ne, Cl, Ar, Kr, Xe, Ra$)

TOTAL NO. OF LIQUID elements - 6 ($Ga, Br, Cs, Hg, Fr, EKa$)

Liquid radioactive element - Francium

N.metal wid highest M.Pt - Carbon

Metal wid highest valency = Plutonium

highest tensile strength - Boron

Most ionic compound = CsF

Strongest base = Cs (OH)

Strongest basic oxide = Cs$_2$O

Most conducting metal = Ag

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**Topic wise grouping of information kind of Dictionary of Organic Chemistry**

Compounds of carbon with other elements in the periodic table:

![Diagram of periodic table with carbon compounds highlighted]
Abscisic acid (ABA) - A PLANT HORMONE once thought to be responsible for the shedding (abscission) of flowers and fruit and for the onset of dormancy in buds (hence its early name, dormin). The compound is associated with the closing of pores (stoma) in the leaves of plants deprived of water.

Absolute configuration - A particular molecular configuration of a CHIRAL molecule, as denoted by comparison with a reference molecule or by some sequence rule. There are two systems for expressing absolute configuration in common use: the D-L convention and the R-S convention.

Absorption
1. A process in which a gas is taken up by a liquid or solid, or in which a liquid is taken up by a solid. In absorption, the substance absorbed goes into the bulk of the material. Solids that absorb gases or liquids often have a porous structure. The absorption of gases in solids is sometimes called sorption. There is a distinction between absorption (in which one substance is assimilated into the bulk of another) and ADSORPTION (which involves attachment to the surface). Sometimes it is not obvious which process is occurring. For example, a porous solid, such as activated CHARCOAL may be said to absorb a large volume of gas, but the process may actually be adsorption on the high surface area of internal pores in the material.

2. The process in which electromagnetic radiation, particles, or sound waves lose energy in passing through a medium. Absorption involves conversion of one form of energy into another.

Accelerator - A substance that increases the rate of a chemical reaction. In this sense the term is synonymous with CATALYST. It is common to refer to catalysts as ‘accelerators’ in certain industrial applications. For example, accelerators are used in the VULCANIZATION of rubber and in the polymerization of adhesives. Also, in the production of composite materials using polyester resins a distinction is sometimes made between the catalyst (which initiates the polymerization reaction) and the accelerator (which is an additional substance making the catalyst more effective). The terms promoter and activator are used in a similar way.

Acceptor - The atom or group to which a pair of electrons is donated in forming a COORDINATE BOND.

Acenaphthene - (C_{12}H_{10}) A colorless crystalline derivative of naphthalene, used in producing some dyes.
Acetal - A type of compound formed by reaction of an alcohol with either an aldehyde or a ketone. The first step in formation of an acetal is the formation of an intermediate, known as a hemiacetal. For example, ethanal (acetaldehyde; CH₃CHO) reacts with ethanol (C₂H₅OH) as follows: CH₃CHO + C₂H₅OH ⇌ CH(OH)(CH₃)(C₂H₅O). The hemiacetal has a central carbon atom (from the aldehyde) attached to a hydrogen, a hydroxyl group, a hydrocarbon group (methyl - CH₃), and an alkoxy group (C₂H₅O). If a ketone is used rather than an aldehyde, the resulting hemiacetal contains two hydrocarbon groups. For example, reaction of the ketone R₁COR₂ with the alcohol R₃OH is:

R₁COR₂ + R₃OH ⇌ CR₁R₂(OH)(OR₃)

The formation of a hemiacetal is an example of nucleophilic addition to the carbonyl group of the aldehyde or ketone. The first step is attack of the lone pair on the O of the alcohol on the (positively charged) C of the carbonyl group. This is catalyzed by both acids and bases. Acid catalysis occurs by protonation of the O on the carbonyl, making the C more negative and more susceptible to nucleophilic attack. In base catalysis the OH⁻ ions from the base affect the -OH group of the alcohol, making it a more effective nucleophile.

In general, hemiacetals exist only in solution and cannot be isolated because they easily decompose back to the component alcohol and aldehyde or ketone. However, some cyclic hemiacetals are more stable. For example, cyclic forms of sugar molecules are hemiacetals.

Further reaction of hemiacetals with another molecule of alcohol leads to a full acetal. For example:

CH(OH)(CH₃)(OC₂H₅) + C₂H₅OH ⇌ CH(CH₃)(OC₂H₅)₂

The overall reaction of an aldehyde or ketone with an alcohol to give an acetal can be written: R₁COR₂ + R₃OH ⇌ CR₁R₂(OR₃)₂

It is also possible to have “mixed” acetics with the general formula CR₁R₂(OR₃)-(OR₄). Note that if the acetal is derived from an aldehyde, then R₁ and/or R₂ may be a hydrogen atom. The mechanism of formation of an acetal from a hemiacetal is acid catalyzed. It involves protonation of the -OH group of the hemiacetal followed by loss of water to form an oxonium ion, which is attacked by the alcohol molecule.
Formerly it was conventional to use the terms ‘hemiacetal’ and ‘acetal’ for compounds formed by reaction between aldehydes and alcohols. Similar reactions between ketones and alcohols gave rise to compounds called hemiketals and ketals. Current nomenclature uses ‘hemiacetal’ and ‘acetal’ for compounds derived from either an aldehyde or a ketone, but reserves ‘hemiketal’ and ‘ketal’ for those derived from ketones. In other words, the ketals are a subclass of the acetals and the hemiketals are a subclass of the hemiacetals.

Achiral - Describing a molecule that does not have chiral properties; i.e. one that does not exhibit optical activity.

Bond fission

A covalent bond is formed when electrons are shared between two atoms in the classical sense. A single bond (sigma bond) is thus made up of two electrons. Now a chemical reaction takes place when old bonds are broken and new ones are created. So how can one break a single bond—there are plainly two ways to go about breaking a bond as shown below.

Homolytic fission

Homolytic fission is where each atom of the bond keeps an electron each resulting in species called free radicals. Radicals are important intermediates in organic chemistry and we will talk about them later. As the bond breaks to give two similar species each keeping an electron this form of bond breaking is called Homolytic Fission.
Heterolytic fission

\[ \text{H}_3\text{C}^-\text{OH} \rightarrow \text{CH}_3^+ + \text{OH}^- \]

Heterolysis

In this case we can see that one of the atoms carry a negative charge after bond cleavage indicating that it has both the electrons of the bond and the other has no electrons at all. Hence it is electron deficient thus positively charged. As the electrons are not divided equally after bond cleavage this is called Heterolytic Fission. In a case the C atom carries a positive charge it is called a carbocation and in the case it carries both the electrons of the broken bond and is negatively charged, it is called a Carbanion. Carbocation and Carbanions are the most important carbon intermediates in organic chemistry. Please note that both types of fissions are applicable to both homoatomic and heteroatomic bonds (bonds between two different atoms say C-N or C-O).

Free radicals

These are neutral intermediates, formed due to homolytic cleavage of a single bond. Some common bonds which cleave to give free radicals in organic chemistry are shown: C-O, C-Cl, C-Br, C-I, C-C, C-H. Carbon free radicals are mainly generated by:

i. Photolysis (action of light) like acetone alpha cleavage
ii. Other radical initiator like allylic bromination by N-Bromosuccinimide (NBS)

There has been a certain degree of debate as to what the shape and geometry of a free radical is like. Revisiting the theory of hybridization, there can be two basic shapes of these radicals.

If the centre carbon atom of the radical is sp\(^3\) hybridized (remember the one which was made of one s and three orbitals as in CH\(_4\)), the geometry will be tetrahedral.\(^2\) But in the case of a radical there are only three groups attached to the sp\(^3\) hybridized carbon atom so they we will have a shape of what resembles a pyramid—it’s a tetrahedron with its head cut off. So sp\(^3\) hybridized radicals are pyramidal in shape. The single electron of the radical would then be housed in a sp\(^3\) orbital. The other option is sp\(^2\) hybridization. In that case the C atom is sp\(^2\) hybridized, so as discussed previously the shape would be planar with the single electron in the unhybridized p-orbital with the three substituents having sp\(^2\) hybridized bonds.

So to summarize free radicals:
Formed under activation by light or use of additional compounds called Radical Initiators.

- They are very reactive, because they have an unpaired electron which wants to get paired up.
- They are either pyramidal or planar with the lone electron in their sp$^3$ or p orbitals respectively.
- Because of their high reactivity, they tend to be less selective. In simple terms it means that it sometimes difficult to predict what products are formed in reactions which involve free radicals and we actually get several products from a single reaction.

This reaction shows the formation of two products with the Br atom attached to different carbons.

**Carbocations**

Carbocations are formed from the heterolytic cleavage of a carbon-heteroatom (meaning a non carbon atom in general) bond where the other atom is more electronegative than carbon like a C-O, C-N, C-X (X can be Cl, Br, I, etc) bond. This is quite logical as after the cleavage if a carbocation is to be formed the two electrons of the bond must go to the other atom. And this is favoured if that other atom is electronegative. Carbocations can be made in difficult conditions by using so-called superacids, developed by George Olah (Nobel Prize, 1994), which helps stabilize these intermediates substantially to be analyzed. Formation of carbocations can be assisted by using cations like Ag$^+$, with alkyl halides as substrates.

The precipitating out of the silver salt forces the equilibrium to shift towards the forwards reaction.

A Similar reaction is Finkelstein reaction is particularly useful for preparing iodoalkanes. The iodoalkanes are obtained by heating chloro or bromoalkanes with a concentrated solution of sodium iodide in dry acetone.

In Acetone after Reflux (Heating in enclosed container) for a long time [ Refluxing is a process of heating a liquid in a flask provided with a condenser. The vapours of the liquid which rise up get condensed back into the flask. ]

RX + NaI ------ > RI + NaX where X = Cl, Br, and R is an Alkyl group

Sodium chloride and sodium bromide being less soluble in acetone get precipitated from the solution and can be removed by filtration. This also prevents the backward reaction to occur according to Le Chatelier's principle. The reaction gives the best results with primary halides.
With iodide, the solvate $NaI \cdot 3(CH_3)CO$ can be formed, in which each Na$^+$ is coordinated by 6 acetone ligands via oxygen lone pairs, and the I$^-$ ions fill in the gaps between these octahedral units, being surrounded by the methyl groups of the acetones. I$^-$ has a larger ionic radius compared to Cl$^-$ and Br$^-$ and thus fills the gap completely, thereby minimizing empty space in the lattice and its distance to Na$^+$, which is, however, still larger than in solvent-free sodium iodide. This larger distance between the ions decreases the lattice energy, which in turn makes the compound readily soluble in acetone. Cl$^-$ and Br$^-$ are too small to fit in these gaps, and as the cation-anion distance becomes too large, the only way to minimize the lattice energy is the formation of a solvent-free structure NaX (X = Cl$^-$, Br$^-$). When the lattice energy is larger than the energy released by solvation of the ions, namely that of Na$^+$ by complexation with acetone, the compound becomes insoluble and precipitates from the solution.

The positively charged carbon atom in carbocations is $sp^2$ hybridized, which means it’s planar as we know by now. The three substituents of the carbocation lie in a plane leaving the unhybridized empty p orbital perpendicular to them.

These intermediates react with species which are electron rich (quite obvious) and being charged are stabilized in polar solvents. (Just as Na$^+$ is soluble and stable in polar water). Carbocations are important intermediates in most mechanisms along with carbanions as we shall see later.

To summarize carbocations:

- Formed due to heterolysis of a C-X bond (where X is more electronegative) and thus has a positive charge.
- Planar in shape ($sp^2$ hybridized carbon), with empty p orbital perpendicular to the plane of the molecule.
- Reactive towards electron rich species.

Carbanions

These are intermediates also formed as a result of heterolysis, but here the electron pair from the bond is kept by the carbon atom. From what we saw earlier the more electronegative atom keeps the electrons, so in this case carbon must the more electronegative of the two atoms making up the bond. Now there are only a few atoms (non-metals; metals are not usually part of organic chemistry) which are less electronegative, so the most common bond cleavage which yields carbanions is the C-H bond. The ease of breaking this bond and creating a carbanion is also a measure of the compound’s acidity, because a H$^+$ is also generated with the carbanion, which makes the molecule an acid in the Bronsted sense.

Carbanions have three groups attached to each other and a lone pair of electrons which gives it its negative charge (similar to the ammonia molecule where the central N has 3 Hs and a lone pair of electrons). So its geometry is pyramidal (tetrahedral but since there is no fourth group again it’s like a tetrahedral with head cut off) and the carbon atom is $sp^3$ hybridized.

Carbanions are also stable in polar solution (electrostatic stabilization).

To summarize carbanions:

- Formed due to heterolysis of a C-X bond (where X is less electronegative) and thus has a negative charge.
- Pyramidal in shape ($sp^3$ hybridized) with the excess electrons placed in one $sp^3$ hybrid orbital.
- Reactive towards positively charged (electron deficient species).
Stability of intermediates

Most organic reactions take place via formation of intermediates. So the study of different intermediates would help us predict the course of the reaction and the main aspect to look at would be their stability. No organic mechanism has been conclusively ‘PROVEN’, all the mechanism we see are the most plausible ones derived from many experiments, a major component of which is isolating and studying the intermediates. It is difficult to say that a certain mechanism is absolutely correct, but it is quite simple to point out an incorrect mechanism. One of the ways a chemist would confirm an incorrect mechanism is if it involves a very unstable intermediate. The good thing about this is that with a few empirical rules and principles in mind, it is quite simple to assign relative stability of intermediates like radicals, carbocations and carbanions. And what is even better is that we have already discussed these principles.

For carbocations and free radicals (both electron poor species), any group which donates electron density to the carbon centre would stabilize it and inversely electron withdrawing groups would increase electron deficiency on the carbon centre leading to destabilization. (Remember charge is not desirable, the most stable species are usually neutral). So following the same logic the effect should just be opposite in the case of carbanions as they are electron rich (negatively charged) instead of being electron deficient like the above two. So groups which pull away electrons from the charged carbon atom would have a stabilizing effect whereas electron donation would destabilize the intermediate as it loads more negative charge on an already negatively charged atom.

The name of a complex radical is considered to start with the first letter of its complete name.

dimethylpentyl (as a complete single substituent) is alphabetized under "d", thus 7-(1,2-Dimethylpentyl)-5-ethyltridecane
In cases where names of complex radicals are composed of identical words, preference for citation is given to that radical which contains the lowest locant at the first cited point of difference in the radical.

4-Ethyl-5-methyloctane

4-Isopropyl-5-propylpropane

If two or more side chains are in equivalent positions the one to be assigned the lower number is that cited first in the name.

4-Ethyl-5-methyloctane

4-Isopropyl-5-propylpropane

The lowest sum rule.

2,3,5-Trimethyl-4-propylheptane (not 3,5,6-Trimethyl-4-propylheptane)

4-Isobuty1-2,5-dimethylheptane (not 4-Isobutyl-2,6-dimethylheptane)
Cyclopentane 1-Methyl-3-propylcyclohexane

Alphabetical order of numbering

More branched carbon gets lower number

3-Ethyl-1,1-dimethylcyclohexane (not 1-ethyl-3,3-dimethylcyclohexane)

CLASSIFICATION OF ORGANIC COMPOUNDS

Organic compounds

- Acyclic or Open chain compounds (I)
- Cyclic or Closed chain or Ring compounds (II)

Homocyclic or Carbocyclic compounds

- Alicyclic compounds
- Aromatic compounds

Benzenoid compounds

Heterocyclic compounds

Non-benzenoid compounds
Alicyclic or closed chain or ring compounds

Alicyclic (aliphatic cyclic) compounds contain carbon atoms joined in the form of a ring (homocyclic). Sometimes atoms other than carbon are also present in the ring (heterocyclic).

Some examples are

- Cyclopropane
- Cyclohexane
- Cyclohexene
- Tetrahydrofuran

Nomenclature of Substituted Benzene Compounds

For IUPAC nomenclature of substituted benzene compounds, the substituent is placed as prefix to the word benzene as shown in the following examples.

- Methylbenzene (Toluene)
- Chlorobenzene (Anisole)
- Aminobenzene (Anilide)
- Nitrobenzene
- Bromobenzene

How Isomers are made?

(a) Normal to branched chain in alkane: $n$-Alkane is heated with $\text{AlCl}_3$ at 570 K to give branched chain

$$\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_3 \xrightarrow{\text{AlCl}_3, 570 \text{ K}} \text{CH}_3-\text{CH}-\text{CH}_2-\text{CH}_3$$

(b) Shift of double bond

In the presence of catalyst like $\text{Al}_2(\text{SO}_4)_3$, alkene undergo isomerization at high temperature (770 – 970 K).

$$\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2=\text{CH}_2 \rightarrow \text{CH}_3\text{CH}_2\text{CH}=\text{CHCH}_3$$

(c) Shift of triple bond

$$\text{CH}_3\text{CH}=\text{CH}_2 \xrightarrow{\text{KOH}, \text{ethanol}} \left[\text{CH}_3\text{CH}=\text{C}=\text{CH}_2\right] \rightarrow \text{CH}_3-\text{C}=\text{C}–\text{CH}_3$$

CBSE Standard 12 Chemistry Survival Guide - Reduction Methods by Prof. Subhashish Chattopadhyay
SKMClasses Bangalore Useful for IIT-JEE, I.Sc. PU-II, Boards, IGCSE IB AP-Chemistry and other exams
Epimers

Anomers

Epimer Anomer comparison
Epimers are monosaccharides that differ in chirality at only one carbon. In the straight-chain format, epimers will have H and OH-substituents switched at one backbone carbon, but not at any others.

Anomers are special epimers; in cyclic forms of one single monosaccharide, anomers differ in chirality at the anomeric (hemiacetal) carbon only. In the straight-chain format, anomers will have the same configuration.
Various Methods of Reduction used in Organic Chemistry

(a) \( CH_3CH=CHCHO \xrightarrow{H_2, Ni} CH_3CH=CHCH_2OH \)
(b) \( CH_3CH=CHCHO \xrightarrow{9-BBN} HOCHCH=CHNH \xrightarrow{CH_3CH=CHCH_2OH} 9-BBN \text{ is 9-Borabicyclo[3.3.1]nonane} \)
(c) \( CH_2=CHCHO \xrightarrow{Zn + Conc. HCl} CH_3CH=CHCH_2OH \)
\( \text{Conjugated reduction} \)
\( \text{Weiss-Kieser reduction} \)
(d) \( CH_2=CHOH \xrightarrow{LiAlH_4} CH_3CHCH_3 \)
(e) \( RCOOH \xrightarrow{1. LiAlH_4, 2. H_2O} RCH_2OH \)
(f) \( \text{Only one nitro group is reduced.} \)

Various methods of Oxidation

**Oxidation**

(a) \( RCH_2OH \xrightarrow{Pyridinium chlorochromate} CH_3CH=CHCHO \)
(b) \( R'CHOH \xrightarrow{K_2Cr_2O_7, H_2O} R'COOH \)
(c) \( RCH_2OH \xrightarrow{KMnO_4} RCOOH \)
(d) \( \text{RCH}=\text{CHCHO} \xrightarrow{Tollens reagent} \text{RCH}=\text{CHCOOH} \)
Synthesis of p-bromonitrobenzene in 2 steps

a synthesis of p-bromonitrobenzene from benzene in two steps.

\[ \text{Br}_2 \xrightarrow{\text{Fe}} \text{Br} \xrightarrow{\text{HNO}_3/\text{H}_2\text{SO}_4} \text{BrNO}_2 \]  
\[
\begin{align*}
\text{ortho} & \quad 38\% \\
\text{para} & \quad 62\%
\end{align*}
\]

Fractional crystallization 
para-isomer crystallizes out first

Secondary alcohol to tertiary alcohol

\[ \text{CH}_3\text{CHCH}_3 \xrightarrow{\text{K}_2\text{Cr}_2\text{O}_7} \text{CH}_3\text{CCH}_3 \xrightarrow{1. \text{CH}_3\text{MgBr}, 2. \text{H}^+} \text{CH}_3\text{C}\text{OH} \]

Prepare m-bromobenzodibenzoic from benzene

Alternatively, we may proceed as follows:

\[ \text{HNO}_3/\text{H}_2\text{SO}_4 \atop 80^\circ \text{C} \]
Secondary alcohol to Primary alcohol

\[
\text{CH}_3\text{CH}_2\text{CH}_2\text{OH} \xrightarrow{\text{conc. H}_2\text{SO}_4} \text{CH}_3\text{CH}-\text{CH}_2 \xrightarrow{\text{HBr, peroxide}} \text{CH}_3\text{CH}_2\text{CH}_2\text{Br} \xrightarrow{\text{aq. KOH}} \text{CH}_3\text{CH}_2\text{CH}_2\text{OH}
\]

To convert Ethylebenzene to Benzene and Ethylebenzene to phenylpropionic acid

Show the steps to carry out the following transformations.
(i) Ethylebenzene → benzene

\[
\text{CH}_3\text{CH}_3 \xrightarrow{[O]} \text{COOH} \xrightarrow{\text{soda lime}}
\]

(ii) Ethylebenzene → 2-phenylpropionic acid.

\[
\text{CH}_3\text{CH}_3 \xrightarrow{\text{Br}_2, h_v} \text{BrCH}_3 \xrightarrow{\text{KCN}} \text{CH}_3 \xrightarrow{\text{H}^+} \text{CHCOOH}
\]

Alcohol to alcohol with one carbon more

\[
\text{CH}_3\text{OH} \xrightarrow{\text{PBr}_3} \text{CH}_3\text{Br} \xrightarrow{\text{KCN}} \text{CH}_3\text{CN} \xrightarrow{[\text{H}]} \text{CH}_3\text{CH}_2\text{NH}_2 \xrightarrow{\text{HNO}_2} \text{CH}_3\text{CH}_2\text{OH}
\]

Carry out the following transformations in not more than three steps.

Alcohol to alcohol with one carbon less

\[
\text{CH}_3\text{CH}_2\text{OH} \xrightarrow{\text{[O]}} \text{CH}_3\text{COOH} \xrightarrow{\text{soda lime}} \text{CH}_4 \xrightarrow{\text{Cl}_2, h_v} \text{CH}_3\text{Cl} \xrightarrow{\text{aq. KOH}} \text{CH}_2\text{OH}
\]
Conversion of Aniline to Benzylamine

How would you bring about the following conversion (in 3 steps)?

Aniline $\rightarrow$ Benzylamine

(i) Carbon-oxygen bond lengths in formic acid are different but are the same in sodium formate. Justify.

(ii) Phenate ion has more number of contributing structures than benzoate ion; but still benzoic acid is a stronger acid. Explain.

Solution. (i) In sodium formate, the contributing structures for the anion are equivalent while these are not the same in formic acid.

Thus, carbon-oxygen bond length in formate ion is the same for both the bonds while these are different in formic acid.

(ii) In phenate ion, the negative charge is dispersed only one electronegative oxygen atoms while there are two available oxygen atoms in benzoate ion to disperse the negative charge.
Amine to amine containing one carbon more

\[ \text{RCH}_2\text{NH}_2 \xrightarrow{\text{HNO}_2/0^\circ\text{C}} \text{RCH}_2\text{OH} \xrightarrow{\text{PBr}_3} \text{RCH}_2\text{Br} \xrightarrow{\text{NaCN}} \text{RCH}_2\text{CN} \xrightarrow{\text{H}_2/\text{Ni}} \text{RCH}_2\text{CH}_2\text{NH}_2 \]

Synthesis of 4-methoxyphenol from bromobenzene

How would you synthesise 4-methoxyphenol from bromobenzene is NOT more than five steps? State clearly the reagents used in each step and show the structure of the intermediate compounds in your synthetic scheme.

The introduction of $\text{NO}_2$ group at para position in bromobenzene facilitates the nucleophilic replacement of $\text{Br}$ by $\text{OCH}_3$.

The negative charge is strongly stabilised by resonance involving para-nitro group.

Write chemical tests to distinguish

**Solution.** Formic acid $\left( \begin{array}{c} \text{H} \\ \text{C}--\text{OH} \end{array} \right)$ contains

both an aldehyde $\left( \begin{array}{c} \text{H} \\ --\text{C}=\text{O} \end{array} \right)$ as well as carboxyl.
group \( \text{C}(-\text{OH}) \) but acetic acid contain only a carboxyl group. Formic acid behaves as reducing agent whereas acetic acid does not.

(a) Formic acid reduces Tollen’s reagent to metallic silver but acetic acid does not.

\[
\text{HCOOH} + 2[\text{Ag(NH}_3\text{)}_2]^{+} + 2(\text{OH})^{-} \rightarrow 2\text{Ag} \downarrow + \text{CO}_2 \uparrow + 2\text{H}_2\text{O} + 4\text{NH}_3
\]

silver mirror

No silver mirror is formed with acetic acid.

(b) Formic acid reduced Fehling solution to red ppt. of Cu$_2$O but acetic acid does not.

\[
\text{HCOOH} + 2\text{Cu}^{2+} + 4(\text{OH})^{-} \rightarrow \text{Cu}_2\text{O} \downarrow + \text{CO}_2 \uparrow + 3\text{H}_2\text{O}
\]

Fehling solution red ppt. (cuprous oxide)

Amine to amine containing one carbon less

\[
\begin{align*}
\text{RCH}_2\text{NH}_2 \rightarrow & \text{HNO}_2 \rightarrow \text{RCH}_2\text{OH} \rightarrow \text{RCOOH} \rightarrow \text{SOCl}_2 \rightarrow \text{RCOCl} \rightarrow \text{NH}_3 \rightarrow \text{RCONH}_2 \rightarrow \text{OBr}^{-} \rightarrow \text{RNH}_2
\end{align*}
\]

Convert Benzoic acid to meta fluorobenzoic acid (2-fluorobenzoic acid)

Convert

\[
\begin{array}{c}
\text{COOH} \\
\text{metafluoro benzoic acid}
\end{array}
\]

\[
\begin{array}{c}
\text{COOH} \\
\text{(not more than 3 steps)}
\end{array}
\]

\[
\begin{array}{c}
\text{F} \\
\text{O} \\
\text{HO}
\end{array}
\]

\[
\begin{array}{c}
\text{F} \\
\text{O} \\
\text{HO}
\end{array}
\]
Convert Nitrobenzene to meta hydroxynitrobenzene (or 4-nitrophenol)

Nitrobenzene resonance structure

4 nitrophenol or metahydroxynitrobenzene
Write down the reactions involved in the preparation of the following using the reagents indicated against each in parenthesis:

(i) Ethylbenzene from benzene \([\text{C}_7\text{H}_8\text{OH}, \text{PCL}_3, \text{anhydrous AlCl}_3]\)

(ii) Propanoic anhydride from propanol \([\text{AgNO}_3/\text{NH}_4\text{OH}, \text{P}_2\text{O}_5]\)

(iii) Acetoxime from acetaldehyde \([\text{K}_2\text{Cr}_2\text{O}_7/\text{H}^+, \text{Ca(OH)}_2\text{ and NH}_2\text{OH.HCl}]\)

(i) \(\text{C}_7\text{H}_8\text{OH} + \text{PCL}_3 \rightarrow \text{C}_7\text{H}_8\text{Cl} + \text{POCl}_3 + \text{HCl}\)

\(\text{C}_7\text{H}_6 + \text{C}_2\text{H}_4\text{Cl} \xrightarrow{\text{AlCl}_3} \text{C}_8\text{H}_9\text{C}_2\text{H}_3 + \text{HCl}\)

(ii) \(\text{C}_2\text{H}_5\text{OH} \xrightarrow{\text{AgNO}_3/\text{NH}_4\text{OH}} \text{C}_2\text{H}_5\text{COOH}\)

\(2\text{C}_2\text{H}_5\text{COOH} \xrightarrow{\text{P}_2\text{O}_5} (\text{C}_2\text{H}_5\text{CO})_2\text{O}\)

(iii) \(\text{CH}_3\text{CHO} \xrightarrow{\text{K}_2\text{Cr}_2\text{O}_7/\text{H}^+} \text{CH}_3\text{COOH}\)

\(\text{CH}_3\text{COOH} \xrightarrow{\text{Ca(OH)}_2} (\text{CH}_3\text{COO})_2\text{Ca}\)

\((\text{CH}_3\text{COO})_2\text{Ca} \xrightarrow{\text{heat}} \text{CH}_3\text{COCH}_3 + \text{CaCO}_3\)

\(\text{CH}_3\text{COCH} \xrightarrow{\text{NH}_2\text{OH}} \text{C} := \text{N} \text{OH}\)

Many conversions or preparations:

Benzene to p-toluic acid

\(\text{CH}_3\text{Cl} \xrightarrow{\text{AlCl}_3} \text{CH}_3\text{Br} \xrightarrow{\text{Fe}} \text{CH}_3\text{Br} \xrightarrow{\text{Br}} \text{BrBr}\)

Benzene to m-chlorobenzoic acid

\(\text{CH}_3\text{Cl} \xrightarrow{\text{AlCl}_3} \text{CH}_3\text{Br} \xrightarrow{\text{KmNO}_4} \text{Cl}_2 \xrightarrow{\text{Fe}} \text{COOH}\)

CBSE Standard 12 Chemistry Survival Guide - Reduction Methods by Prof. Subhashish Chattopadhyay
SKMClasses Bangalore Useful for IIT-JEE, I.Sc. PU-II, Boards, IGCSE IB AP-Chemistry and other exams
Benzene to p-chlorobenzoic acid

Benzene to p-chlorobenzoic acid

\[ \text{CH}_2\text{C}l_2 \xrightarrow{\text{AlCl}_3} \text{CH}_3\text{Cl} \xrightarrow{\text{CH}_2\text{Cl} \xrightarrow{\text{Fe}} \text{Cl} \xrightarrow{\text{K MnO}_4} \text{COOH}} \]

Acetic acid to Malonic acid

\[ \text{CH}_3\text{C}O\text{OH} \xrightarrow{\text{Br}_2, \text{P}} \text{BrCH}_2\text{COOH} \xrightarrow{\text{KCN}} \text{CNCH}_2\text{C}O\text{OH} \xrightarrow{\text{H}_2\text{O}} \text{HOOCCCH}_2\text{C}O\text{OH} \]

Ethyne to propanoic acid

\[ \text{HC}==\text{CH} \xrightarrow{\text{Lindlar catalyst}} \text{H}_2\text{C}==\text{CH}_2 \xrightarrow{\text{HCl}} \text{CH}_3\text{CH}_2\text{Cl} \xrightarrow{\text{KCN}} \text{C}_2\text{H}_5\text{CN} \xrightarrow{\text{H}_2\text{O}} \text{C}_2\text{H}_5\text{C}O\text{OH} \]

Isopropyl alcohol to β-hydroxybutyric acid

\[ \text{CH}_3\text{CHCH}_3 \xrightarrow{\text{Al}_2\text{O}_3, 250^\circ\text{C}} \text{CH}_3\text{CH}==\text{CH}_2 \xrightarrow{\text{HOC}l} \xrightarrow{\text{KCN}} \xrightarrow{\text{H}_2\text{O}} \text{CH}_3\text{CHCH}_2\text{COOH} \]

Acetic acid to Propanoic acid

\[ \text{CH}_3\text{C}O\text{OH} \xrightarrow{\text{LiAIH}} \text{CH}_3\text{CH}_2\text{OH} \xrightarrow{\text{PCl}_3} \text{CH}_3\text{CH}_2\text{Cl} \xrightarrow{\text{KCN}} \text{CH}_3\text{CH}_2\text{CN} \xrightarrow{\text{H}_2\text{O}} \text{CH}_3\text{CH}_2\text{COOH} \]

Ethanoic acid to a mixture of methanoic acid and diphenyl ketone
Ethanoic acid to a mixture of methanoic acid and diphenyl ketone

\[
\begin{align*}
\text{CH}_3\text{COOH} & \quad \text{SOCl}_2 \quad \rightarrow \quad \text{CH}_3\text{COCl} \\
& \quad \text{(acetic acid)} \quad \text{AlCl}_3 \quad \rightarrow \quad \text{C}_6\text{H}_6 \\
& \quad \text{(acetophenone)}
\end{align*}
\]

Alternatively, we may proceed as follows.

\[
\begin{align*}
\text{C}_6\text{H}_5\text{COC}_6\text{H}_5 + \text{HCOOH} & \quad \text{KMnO}_4 \quad \rightarrow \quad \text{C}_6\text{H}_5 \\
& \quad \text{(diphenyl ketone)} \quad \text{[O]} \quad \rightarrow \quad \text{C}_6\text{H}_5 \\
& \quad \text{(formic acid)} \quad \text{H}_2\text{O} \\
\text{CH}_3\text{COOH} & \quad \text{SOCl}_2 \quad \rightarrow \quad \text{CH}_3\text{COCl} \\
& \quad \text{(acetyl chloride)} \quad \text{C}_6\text{H}_5\text{MgBr} \quad \rightarrow \quad \text{CH}_3\text{C}_6\text{H}_5 \\
& \quad \text{excess} \quad \text{H}_2\text{O} \quad \text{Conc. H}_2\text{SO}_4 \quad >150^\circ \text{C}
\end{align*}
\]

Propanoic acid to acetic acid

Propanoic acid to acetic acid

\[
\begin{align*}
\text{CH}_3\text{CH}_2\text{COOH} & \quad \text{NH}_3 \quad \rightarrow \quad \text{CH}_3\text{CH}_2\text{CONH}_2 \\
& \quad \text{Br}_2 / \text{KOH} \quad \rightarrow \quad \text{CH}_3\text{CH}_2\text{NH} \quad \text{HNO}_3 \quad \rightarrow \quad \text{CH}_3\text{CH}_2\text{OH} \\
& \quad \text{heat} \quad \text{H}^+ \quad \rightarrow \quad \text{CH}_3\text{COOH}
\end{align*}
\]
Aniline to 1, 2, 3-tribromobenzene

Ethanal to 2-hydroxy-3-butoenoic acid

Benzene to m-bromophenol

Ethyl alcohol to Vinyl alcohol

Methylamine to ethylamine
Benzene to m-bromotoluene

Benzaldehyde to cyanobenzene

Aniline to Chlorobenzene

Ethylamine to Methylamine
Benzene to m-dibromobenzene

**Benzene to m-dibromobenzene**

\[
\text{Benzene} \xrightarrow{\text{HNO}_3, \text{H}_2\text{SO}_4} \text{Nitrobenzene} \xrightarrow{\text{Br}_2, \text{Fe}} \text{Nitrobenzene (with bromine)} \xrightarrow{\text{Sn}, \text{HCl}} \text{Bromoaniline} \xrightarrow{\text{NaNO}_2, \text{HCl}} \text{Bromoaniline (oxidized)} \xrightarrow{\text{CuBr}} \text{m-Dibromobenzene}
\]

Aniline to p-nitroaniline

**Aniline to p-nitroaniline**

\[
\text{Aniline} \xrightarrow{\text{CH}_3\text{COCl, HCl}} \text{Acetylaniline} \xrightarrow{\text{HNO}_3, \text{H}_2\text{SO}_4} \text{Nitroaniline} \xrightarrow{\text{H}_2\text{O}} \text{Nitroaniline (neutralized)}
\]

Toluene to m-nitrotoluene

**Toluene to m-nitrotoluene**

\[
\text{Toluene} \xrightarrow{\text{HNO}_3, \text{H}_2\text{SO}_4} \text{Nitrotoluene} \xrightarrow{\text{CH}_3\text{(COOH)}_2} \text{Acetylnitrotoluene} \xrightarrow{\text{HNO}_3, \text{H}_2\text{SO}_4} \text{Nitroacetanilide} \xrightarrow{\text{H}_2\text{O}} \text{Acetanilide (neutralized)}
\]
Convert Benzene + Alcohol to α-methylphenylacetic acid

Benzene + alcohol to α-methylphenylacetic acid

\[
\text{C}_2\text{H}_5\text{OH} + \text{C}_6\text{H}_5\text{NH}^+\text{CrO}_4^{2-} \rightarrow \text{CH}_3\text{CHO}
\]

1. Benzene + Br₂ + Fe → Benzene + Mg
2. Benzene + MgBr + CH₃CHO → Benzene + MgCl
3. Benzene + HCl → Benzene + Mg

\[
\text{CH}_3\text{COOH} \leftrightarrow \text{CH}_3\text{MgCl} + \text{CO}_2
\]

Toluene to 3,5 dibromotoluene

Toluene to 3, 5-dibromotoluene

Benzene to p-chloronitrobenzene
Benzene to \( p \)-chloronitrobenzene

\[
\begin{array}{c}
\text{Benzene} \xrightarrow{\text{Cl}_2, \text{Fe}} \text{Benzene} \xrightarrow{\text{HNO}_3, \text{H}_2\text{SO}_4} \text{Benzene} \\
\end{array}
\]

Toluene to 2, 6-dibromotoluene

\[
\begin{align*}
\text{Toluene} & \xrightarrow{\text{HNO}_3, \text{H}_2\text{SO}_4} \text{Toluene} & \xrightarrow{2\text{Br}, \text{Fe}} \text{Toluene} & \xrightarrow{\text{Br}, \text{Fe}} \text{Toluene} & \xrightarrow{\text{H}_3\text{PO}_4} \text{Toluene} \\
& & & & \xrightarrow{\text{HNO}_2} \text{Toluene}
\end{align*}
\]

Benzene to 3, 4-dibromonitrobenzene

\[
\begin{align*}
\text{Benzene} & \xrightarrow{\text{Br}, \text{Fe}} \text{Benzene} & \xrightarrow{\text{HNO}_3, \text{H}_2\text{SO}_4} \text{Benzene} & \xrightarrow{\text{Br}, \text{Fe}} \text{Benzene}
\end{align*}
\]

Benzene to \( m \)-chloronitrobenzene

\[
\begin{align*}
\text{Benzene} & \xrightarrow{\text{HNO}_3, \text{H}_2\text{SO}_4} \text{Benzene} & \xrightarrow{\text{Cl}_2, \text{Fe}} \text{Benzene}
\end{align*}
\]
Nitrobenzene to benzamide

\[
\text{Nitrobenzene to benzamide} \\
\begin{align*}
\text{Nitrobenzene} & \xrightarrow{\text{Sn(HCl), } \text{NH}_2} \text{Benzamide} \\
\begin{array}{c}
\text{NO}_2 \\
\text{H}_3 \text{Cl} \\
\end{array} & \xrightarrow{\text{NaNO}_2/\text{NH}_2 \text{HCl}} \\
\begin{array}{c}
\text{HCN} \\
\text{CN} \\
\text{COOH} \\
\text{CONH}_2 \\
\end{array} & \xrightarrow{\text{KCN, } \text{H}_3 \text{Cl}, \text{273-278 K}} \\
\begin{array}{c}
\text{NH}_2 \\
\text{NH}_3 \text{ heat} \\
\end{array} & \xrightarrow{\text{H}_2 \text{SO}_4} \\
\text{Benzamide} & \\
\end{align*}
\]

Benzene to 4-nitrobenzaldehyde

\[
\text{Benzene to 4-nitrobenzaldehyde} \\
\begin{align*}
\text{Benzene} & \xrightarrow{\text{CH}_3 \text{Cl, } \text{AlCl}_3} \\
\begin{array}{c}
\text{HNO}_3 \\
\text{H}_2 \text{SO}_4 \\
\text{CrO}_3 \\
\text{(CH}_3\text{CO}_2\text{O)} \\
\text{H}_2 \text{O} \\
\text{H}_2 \text{SO}_4 \\
\end{array} & \xrightarrow{\text{CH}_3(\text{OCOCH}_3)_2} \\
\begin{array}{c}
\text{CHO} \\
\text{NO}_2 \\
\text{NO}_2 \\
\text{NO}_2 \\
\text{NO}_2 \\
\end{array} & \xrightarrow{\text{H}_2 \text{O}, \text{H}_2 \text{SO}_4} \\
\text{Benzene to 4-nitrobenzaldehyde} & \\
\end{align*}
\]

Benzene to 4-amino-2-bromotoluene

\[
\text{Benzene to 4-amino-2-bromotoluene} \\
\begin{align*}
\text{Benzene} & \xrightarrow{\text{CH}_3 \text{Cl, } \text{AlCl}_3} \\
\begin{array}{c}
\text{HNO}_3 \\
\text{H}_2 \text{SO}_4 \\
\text{Br}_2 \\
\text{Fe} \\
\text{Fe, H}^+ \\
\end{array} & \xrightarrow{\text{Br}_2} \\
\begin{array}{c}
\text{Br} \\
\text{Br} \\
\text{NO}_2 \\
\text{NO}_2 \\
\text{CH}_3 \\
\text{CH}_3 \\
\end{array} & \xrightarrow{\text{Fe, H}^+} \\
\begin{array}{c}
\text{NH}_2 \\
\text{H}_2 \text{SO}_4 \\
\text{CH}_3 \\
\text{CH}_3 \\
\text{NO}_2 \\
\text{NO}_2 \\
\text{CH}_3 \\
\text{CH}_3 \\
\text{NO}_2 \\
\end{array} & \xrightarrow{\text{Fe, H}^+} \\
\text{Benzene to 4-amino-2-bromotoluene} & \\
\end{align*}
\]

2,4-Dinitrophenol (DNP)
Convert a mixture of cis-2-pentene and trans-2-pentene into cis-2-pentene or trans-2-pentene

A mixture of cis-2-pentene and trans-2-pentene into cis-2-pentene or trans-2-pentene

Benzene to p-chlorobenzylalcohol

Benzene to p-chlorobenzylalcohol
Convert Propanol to α-hydroxypropanoic acid

\[
\text{Propanol to } \alpha\text{-hydroxypropanoic acid} \\
\text{CH}_3\text{CH}_2\text{CH}_2\text{OH} \xrightarrow{\text{Kmno}_4} \text{CH}_3\text{CH}_2\text{COOH} \xrightarrow{\text{Br}_2/P} \text{CH}_3\text{CHCOOH} \xrightarrow{\text{OH}^-} \text{CH}_3\text{CHCOOH}
\]

4-chloropentane-2-one

3-Bromo-4-methylpentanoic acid

\[
\begin{align*}
\text{Vanillin} & : \text{CH}_3 \quad \text{Salicylaldehyde} : \text{CHO} \quad \text{Cinnamonaldehyde} : \text{CH} = \text{CHO} \\
\text{p,p'}\text{- dihydroxybenzophenone} & : \text{HO} \quad \text{Hex-2-ene-4-ynoic acid} : \text{CH}_3 \\
\text{Heptan-2-one} & : \text{O} 
\end{align*}
\]
Benzene to Mandelic Acid

4-Bromo-2-methylhexane

Heptanal

1-(4-Methoxyphenyl)-3-phenylprop-2-en-1-one

4-phenylprop-3-ene-2-one
3-phenylprop-2-ene-1-al

\[
\text{CH}=\text{CH} \longrightarrow \text{CHO}
\]

3-phenyl-prop-2-ene-1-ol

\[
\text{CH}=\text{CH} \longrightarrow \text{CH}_2\text{OH}
\]

cyclopentancarbaldehyde

Benzophenone also diphenylmethanone
Tollen’s Reagent

\[
\text{RCHO}(aq) + 2\text{Ag(NH}_3\text{)}_2^+ (aq) + 3\text{OH}^-(aq) \rightarrow \text{RCOO}^- (aq) + 2\text{Ag(s)} + 4\text{NH}_3 (aq) + 2\text{H}_2\text{O}
\]

An aldehyde

An aldose

\[
\begin{align*}
\text{Ag(NH}_3\text{)}_2^+ & \quad \rightarrow \\
\text{RCO}^- & \quad + \quad \text{Ag(s)}
\end{align*}
\]

Tollens’ reagent (clear solution)

Carboxylate anion

Silver

An aldose

\[
\begin{align*}
\text{Cu(citrate)}_{2}^{2-} & \quad \rightarrow \\
\text{RCO}^- & \quad + \quad \text{Cu}_2\text{O(s)}
\end{align*}
\]

Benedict’s reagent (blue solution)

Carboxylate anion

Brick-red precipitate

Benzene to 2,4-dinitrobenzaldehyde

\[
\begin{align*}
\text{CH}_3\text{Cl} & \quad \rightarrow \\
\text{CH}_3 & \quad \rightarrow \\
\text{CH}_3\text{NO}_2 & \quad \rightarrow \\
\text{CHC}_2\text{O} & \quad \rightarrow \\
\text{CHO} & \quad \rightarrow
\end{align*}
\]

Acetaldehyde to Acetylene

\[
\begin{align*}
\text{CH}_3\text{CHO} & \quad \rightarrow \\
\text{CH}_3\text{CH}_2\text{OH} & \quad \rightarrow \\
\text{CH}_2\text{=CH}_2 & \quad \rightarrow \\
\text{CH}_3\text{CH}=\text{CH}_2 & \quad \rightarrow
\end{align*}
\]
Identify the compounds

compound contains C, H and O unreactive towards Na (Sodium)

A compound (X) containing only C, H and O is unreactive towards sodium. It does not add bromine. It also does not react with Schiff’s reagent. On refluxing with an excess of hydroiodic acid, X yields only one organic product Y. On hydrolysis Y yields a new compound Z which can be converted to Y by reaction with red phosphorus and iodine. The compound Z on oxidation with potassium permanganate gives a carboxylic acid. The equivalent weight of this acid is 60. What are the compounds X, Y and Z? Write chemical equations leading to the conversion of X to Y. (1981)

Solution
Since the compound is unreactive towards sodium, it is neither alcohol (including phenol) nor carboxylic acid. It is also not an aldehyde. It may be a symmetrical ether because on refluxing with excess of HI, it gives only one product. Thus, we have

$$\text{ROH} + 2\text{HI} \rightarrow 2\text{RI} + \text{H}_2\text{O} \quad \text{(X)}$$

$$2\text{ROH} + \text{I}_2 \rightarrow 2\text{R'C} + \text{H}_2\text{O} \quad \text{(Y)}$$

Now the equivalent weight of R'C is 60. From this, it follows that R' is —CH₃ group and hence R is —CH₂CH₃ group. Thus, the compounds X, Y and Z are

X : CH₃CH₂OCH₂CH₃; \quad Y : CH₃CH₂I; \quad Z : CH₃CH₂OH
Identify the compound
A hydrocarbon reacts with Bromine to give dibromo compound

One mole of a hydrocarbon $A$ reacts with one mole of bromine giving a dibromo compound $C_4H_{10}Br_2$. Substance $A$ on treatment with cold, dilute alkaline potassium permanganate solution forms a compound $C_3H_6O_2$. On ozonolysis, $A$ gives equimolar quantities of propanone and ethanol. Deduce the structural formula of $A$.

Solution
From the products of ozonolysis, we conclude that

\[
\text{propanone} \quad \text{ethanal} \quad (A) \quad 2\text{-methylbut-2-one}
\]

The compound $A$ contains a double bond. This is also confirmed from the fact that the compound $A$ reacts with one mole of bromine. Thus, the given reactions are

\[
\text{CH}_3\text{CH}=\text{CHCH}_3 + \text{Br}_2 \xrightarrow{\text{cold}} \text{CH}_3\text{CH}==\text{CHCH}_3 + \text{CH}_3\text{CH}==\text{CH}_2
\]

Identify the compound
An alkene $A$ on ozonolysis yields acetone and an aldehyde

An alkene $A$ on ozonolysis yields acetone and an aldehyde. The aldehyde is easily oxidized to an acid $B$. When $B$ is treated with bromine in presence of phosphorus, it yields a compound $C$ which on hydrolysis gives a hydroxy acid $D$. This acid can also be obtained from acetone by the reaction with hydrogen cyanide followed by hydrolysis. Identify the compounds $A$, $B$, $C$ and $D$.

Solution
The structure of compound $D$ is easily deduced from the fact that it is obtained by the combination of acetone with hydrogen cyanide followed by hydrolysis.

\[
\text{CH}_3\text{C}=\text{O} \xrightarrow{\text{HCN}} \text{CH}_3\text{C}=\text{CN} \xrightarrow{\text{H}^+} \text{CH}_3\text{C}=\text{COOH} \quad (\text{D})
\]

The conversion $B$ to $C$ and then $C$ to $D$ indicates that the reaction $B$ to $C$ is Hell-Volhard-Zelinsky reaction. Thus, we have

\[
\text{CH}_3\text{C}=\text{O} \xrightarrow{\text{Br}_2\text{P}} \text{CH}_3\text{C}=\text{Br} \xrightarrow{\text{H}_2\text{O}} \text{CH}_3\text{C}=\text{COOH} \quad (\text{C})
\]

Hence, we conclude that the aldehyde from which compound $B$ is obtained by oxidation has the structure

\[
\text{CH}_3\text{CH}=\text{CHO} \quad (\text{B})
\]

Now, the ozonolysis of the compound $A$ gives acetone and 2-methyl-propanal, i.e.
Identify the compound

An aromatic compound contains 69.4% carbon, 5.8% hydrogen.

An aromatic compound contains 69.4% carbon and 5.8% hydrogen. A sample of 0.303 g of this compound was analysed for nitrogen by Kjeldahl’s method. The ammonia evolved was absorbed in 50 mL of 0.05 M sulphuric acid. The excess acid required 25 mL of 0.1 M sodium hydroxide for neutralization. Determine the molecular formula of the compound if its molar mass is 121 g mol$^{-1}$. Draw two possible structures for this compound.

**Solution**

The reactions involved are:

$$2\text{NH}_4 + \text{H}_2\text{SO}_4 \rightarrow (\text{NH}_3)_2\text{SO}_4$$

$$\text{H}_2\text{SO}_4 + 2\text{NaOH} \rightarrow \text{Na}_2\text{SO}_4 + 2\text{H}_2\text{O}$$

Amount of sodium hydroxide to neutralize excess of sulphuric acid = $(25 \text{ mL}) \frac{0.1 \text{ mol}}{1000 \text{ mL}} = \frac{1}{400} \text{ mol}$

Amount of sulphuric acid neutralized with sodium hydroxide $= \frac{1}{2} \left( \frac{1}{400} \text{ mol} \right) = \frac{1}{800} \text{ mol}$

Amount of sulphuric acid taken to start with = $(50 \text{ mL}) \frac{0.05 \text{ mol}}{1000 \text{ mL}} = \frac{1}{400} \text{ mol}$
Identify the compound

An organic compound $C_yH_{2y}O_y$ was burnt with twice the amount of Oxygen

An organic compound $C_xH_yO_z$ was burnt with twice the amount of oxygen needed for complete combustion to $CO_2$ and $H_2O$. The hot gases, when cooled to 0 °C and 1 atm pressure, measured 2.24 L. The water collected during cooling weighed 0.9 g. The vapour pressure of pure water at 20 °C is 17.5 mmHg and is lowered by 0.104 mmHg when 50 g of the organic compound is dissolved in 1000 g of water. Give the molecular formula of the organic compound.

Solution: The combustion reaction is $C_xH_yO_z + (x + y)O_2 \rightarrow xCO_2 + yH_2O$

To start with, the amount of $O_2$ taken is $2x$. Hence, after the combustion reaction, we will be left with the following amounts.

- Amount of oxygen left unreacted = $x$
- Amount of carbon dioxide = $x$
- Amount of water = $y$

When this mixture is cooled to 0 °C and 1 atm, we will be left with oxygen and carbon dioxide. Hence, the amount 2x occupies the given volume of 2.24 L at STP. Hence,

\[
\text{Amount} \times \frac{2.24 \text{ L}}{22.4 \text{ L} \text{ mol}^{-1}} = 0.05 \text{ mol}
\]

Now,

- Mass of water collected = 0.9 g
- Amount of water collected, $y = \frac{0.9 \text{ g}}{18 \text{ g mol}^{-1}} = 0.05 \text{ mol}$

Thus, the empirical formula of the compound is $C_{0.09}H_{0.9}O_{0.09}$, i.e. $C_2H_2O_2$. Now, according to Raoult’s law,

\[
\frac{\Delta P}{p} = x_2 \text{ i.e.} \frac{0.104 \text{ mmHg}}{17.5 \text{ mmHg}} = \frac{(50 \text{ g/mol})}{(1000 \text{ g}/18 \text{ g mol}^{-1})}
\]
Identify the Compound

Alcohol when heated with concentrated H$_2$SO$_4$

An alcohol A, when heated with concentrated H$_2$SO$_4$ gives an alkene B. When B is bubbled through bromine water and the product obtained is dehydrohalogenated with excess of sodamide, a new compound C is obtained. The compound C gives D when treated with warm dilute H$_2$SO$_4$ in presence of HgSO$_4$. D can also be obtained either by oxidizing A with KMnO$_4$ or from acetic acid through its calcium salt. Identify A, B, C and D.

Solution

The given reactions are as follows.

\[
\begin{align*}
A \xrightarrow{\text{conc. H}_2\text{SO}_4} & B \\
B & \xrightarrow{1. \text{Br}_2, 2. \text{-HBr}} C \\
C & \xrightarrow{\text{HgSO}_4/\text{H}_2\text{SO}_4} D
\end{align*}
\]

The reaction of obtaining D from calcium acetate is

\[(\text{CH}_3\text{C(OO)}_2\text{Ca} \rightarrow \text{CH}_3\text{COCOH}_3 + \text{CaCO}_3)\]

Hence, D is acetone. Since the latter is also obtained from the oxidation of alcohol A, compound A will be \(\text{CH}_3\text{CCH}_3\).

1\ OH
Hence, the reactions depicted above are as follows.

\[
\begin{align*}
\text{CH}_3\text{CHCH}_3 & \xrightarrow{\text{conc. H}_2\text{SO}_4} \text{CH}_3\text{CH} = \text{CH}_2 \\
\text{CH}_3\text{CH} = \text{CH}_2 & \xrightarrow{\text{Br}_2} \text{CH}_3\text{CH} \text{Br} \text{Br} \\
\text{CH}_3\text{CCH}_3 & \xrightarrow{+\text{H}_2\text{O}} \text{CH}_3\text{C} = \text{CH} \text{HgSO}_4/\text{H}_2\text{SO}_4
\end{align*}
\]
Certain hydrocarbon was found to contain 85.7% carbon.

A certain hydrocarbon \( A \) was found to contain 85.7% carbon and 14.3% hydrogen. This compound consumes 1 mole equivalent of hydrogen to give a saturated hydrocarbon \( B \). 1.0 g of hydrocarbon \( A \) just decolourized 38.05 g of a 5% per cent solution (by mass) of \( \text{Br}_2 \) in \( \text{CCl}_4 \). Compound \( A \), on oxidation with concentrated \( \text{KMnO}_4 \), gave compound \( C \) (molecular formula \( \text{C}_6\text{H}_x\text{O}_2 \)) and compound \( C \) could easily be prepared by the action of acidic aqueous mercuric sulphate on 2-butyne. Determine the molecular formula of \( A \) and deduce the structures \( A \), \( B \) and \( C \).

**Solution**

The ratio of atoms in the compound \( A \) is \( \text{C} : \text{H} : \frac{85.7}{1} : 14.3 = 7.14 : 14.3 : 1 : 2 \).

Thus, Empirical formula of \( A \) is \( \text{CH}_2 \).

Since the compound \( A \) consumes 1 mole of hydrogen, the molecule of \( A \) contains only one carbon-carbon double bond. From the data on the absorption of bromine, we can calculate the molar mass of \( A \) as shown in the following:

- Mass of bromine absorbed by 1.0 g of hydrocarbon = \( \frac{5}{100} \times 38.05 \) g
- Mass of hydrocarbon absorbing 160 g (= 1 mol) of \( \text{Br}_2 \) = \( \frac{1.0}{(5 \times 38.05/100)} \) × 160 g = 84.1 g.

Hence, Molar mass of \( A \) is 84.1 g mol\(^{-1}\).

The number of repeating \( \text{CH}_2 \) group in one molecule of \( A \) will be \( \frac{84.1}{14} = 6 \) (= 84.1/14). Hence, Molecular formula of \( A \) is \( \text{C}_6\text{H}_{12} \). Now, it is given that

\[
\begin{align*}
\text{C}_6\text{H}_{12} & \xrightarrow{\text{conc. KMnO}_4} \text{C}_4\text{H}_8\text{O}_2 + \text{CH}_3\text{COOH} \quad (\text{A}) \\
\text{C}_4\text{H}_8\text{O}_2 & \xrightarrow{\text{H}_2\text{SO}_4/\text{H}_2\text{SO}_4} \text{CH}_3\text{C} & \text{C} & \text{CH}_3 \quad \rightarrow \text{CH}_3\text{CCH}_2\text{CH}_3 \\
2\text{-butyne} & & & & 2\text{-butanal (C)}
\end{align*}
\]

The compound \( C \) is obtained by the hydration of 2-butyne. Hence, its structure obtained from the reaction is

\[
\begin{align*}
\text{CH}_3\text{C} & \equiv \text{C} \equiv \text{CH}_3 & \xrightarrow{\text{H}_2\text{O}} & \text{CH}_3\text{C} & \equiv \text{CH}_3 \quad \rightarrow \text{CH}_3\text{C} & \equiv \text{CH}_3 \\
2\text{-butyne} & & & & \text{2-butanol (C)}
\end{align*}
\]

A liquid \( X \) having a molecular formula \( \text{C}_6\text{H}_{12}\text{O}_2 \) is hydrolyzed with water.

A liquid \( X \), having a molecular formula \( \text{C}_6\text{H}_{12}\text{O}_2 \) is hydrolysed with water in the presence of an acid to give a carboxylic acid, \( Y \), and an alcohol \( Z \). Oxidation of \( Z \) with chromic acid gives \( Y \). What are the structures of \( X \), \( Y \) and \( Z \)?

**Solution**

Since the hydrolysis of \( X \) gives a carboxylic acid (\( Y \)) and an alcohol (\( Z \)), the compound \( X \) must be an ester. Let it be \( \text{R'OH} \). The compounds \( Y \) and \( Z \) will be \( \text{RCOOH} \) and \( \text{R'OH} \), respectively. Since the oxidation of \( Z \) gives \( Y \), we will have

- \( \text{R'OH} \xrightarrow{[O]} \text{RCOOH} \) or \( \text{RCH}_2\text{OH} \xrightarrow{[O]} \text{RCOOH} \)

Hence, the given compound \( X \) may be written as \( \text{RCOOCH}_2\text{R} \). From this it follows that

\[
\begin{align*}
2\text{R} & \equiv \text{C}_6\text{H}_{12} & \equiv \text{C}_2\text{H}_4 & \equiv \text{C}_2\text{H}_4 & \equiv \text{C}_2\text{H}_4 \\
\text{X} & \equiv \text{CH}_3\text{CH}_2\text{C} & \equiv \text{CH}_2\text{CH}_3 & \equiv \text{Propylpropionate (Y)} & \equiv \text{CH}_2\text{CH}_2\text{COOH} & \equiv \text{Propanoic acid} \\
\text{Z} & \equiv \text{CH}_3\text{CH}_2\text{CH}_2\text{OH} & \equiv \text{Propanol}
\end{align*}
\]
Identify the compound

An unknown compound of carbon, hydrogen, and oxygen contains 69.77% carbon and 11.63% hydrogen and has a molar mass of 86 g mol⁻¹. It does not reduce Fehling’s solution, but forms a bisulphite addition compound and gives a positive iodoform test. What are the possible structures?

**Solution**
The given compound is a ketone as it does not reduce Fehling’s solution, but forms a bisulphite addition compound. It will also contain CH₃C=O group as it shows positive iodoform test.

The ratios of atoms in the compound are

\[
\begin{align*}
& & 12 : 16 : 16 : 1 \\
\text{Hence } & & \text{Empirical formula is } C_6H_{10}O.
\end{align*}
\]

Molar empirical mass = 86 g mol⁻¹; same as the given molar mass

Thus, Molecular formula is C₆H₇O₂.

The structure of the compound will be

\[
\begin{align*}
\text{CH₃C} & \text{CH₂CH₂CH₃ (or) } \\
\text{O} & \text{CH₃CCH₂CH₂CH₃} \\
\text{2-pentanone} & \text{3-methylbutan-2-one}
\end{align*}
\]

Identify the compound

An organic compound A on treatment with acetic acid in the presence of Sulphuric acid

An organic compound A on treatment with acetic acid in the presence of sulphuric acid produces an ester B. The compound A on mild oxidation gives C. The compound C with 50% potassium hydroxide followed by acidification with dilute hydrochloric acid generates A and D. The compound D with phosphorus pentachloride followed by reaction with ammonia gives E. The compound E on dehydration produces hydrocyanic acid. Identify the compounds A, B, C, D, and E.

**Solution**
The given reactions are

\[
\begin{align*}
\text{A} + \text{CH₃COOH} & \xrightarrow{\text{H₂SO₄}} \text{ester; } \\
\text{A} \xrightarrow{\text{mild oxidation}} & \text{C} \xrightarrow{\text{50% KOH}} \text{A} + \text{D} \\
\text{D} & \xrightarrow{\text{PCl₅}} \text{E} \xrightarrow{-\text{H₂O}} \text{HCN}
\end{align*}
\]

The reaction \( \text{C} \xrightarrow{\text{50% KOH}} \text{A} + \text{D} \) is a Cannizzaro reaction and thus the compound C is an aldehyde with no \( \alpha \)-hydrogen. C must be HCHO. From this it follows that A must be CH₃OH as its mild oxidation gives HCHO.

With this fact, we can write the given reactions as shown below.

\[
\begin{align*}
\text{CH₃OH} + \text{CH₃COOH} & \xrightarrow{\text{methyl acetate}} \text{CH₃COOCH₃} \\
\text{CH₃OH} & \xrightarrow{\text{IO₃}} \text{HCHO} \xrightarrow{\text{50% KOH}} \text{CH₃OH} + \text{HCN}
\end{align*}
\]

Hence

\[
\begin{align*}
\text{HCOOH} & \xrightarrow{\text{PCl₅}} \text{HCOCI} \xrightarrow{\text{NH₃}} \text{HCONH₂} \xrightarrow{-\text{H₂O}} \text{HCN}
\end{align*}
\]

\[
\begin{align*}
\text{A} : \text{CH₃OH} & \text{ methanol } \\
\text{B} : \text{CH₃COOCH₃} & \text{ methylethonate } \\
\text{C} : \text{HCHO} & \text{ methanal } \\
\text{D} : \text{HCOOH} & \text{ methanoic acid } \\
\text{E} : \text{HCONH₂} & \text{ methanamide}
\end{align*}
\]
Iodoform Test

\[
\text{RCH}_3 + 3\text{I}_2 + 4\text{NaOH} \rightarrow \]

\[
\text{RCOO}^-\text{Na}^+ + 3\text{NaI} + 3\text{H}_2\text{O} + \text{CH}_3\text{I} (\text{s})
\]

\[
\text{HO}:
\]

\[
\text{R} \quad \text{I} \quad \text{I} \quad \text{R} \quad \text{R} \quad \text{OH} \quad \text{R} \quad \text{R}
\]

\[
\text{RCOOH} \rightarrow \text{RCOO}^-\text{Na}^+ + \text{CH}_3\text{I}
\]

\[
\text{RCH}_2\text{CH}_3 + \text{I}_2 + \text{NaOH} \rightarrow \text{RCOO}^-\text{Na}^+ + \text{CH}_3\text{I}
\]

\[
\text{RCHCH}_3 + \text{I}_2 + \text{NaOH} \rightarrow \text{RCOO}^-\text{Na}^+ + \text{CH}_3\text{I}
\]

\[
\text{C}_3\text{H}_3\text{O} + \text{DH}^+ \rightarrow \text{CH}_3 + \text{R} - \text{CO}^-\text{Na}^+
\]
Identify the compound

An organic compound X, on analysis gives 24.24 per cent carbon and 4.04 per cent hydrogen. Further, sodium extract of 1.0 g. of X gives 2.90 g. of silver chloride with acidified silver nitrate solution. The compound X may be represented by two isomeric structures, Y and Z. The compound Y on treatment with aqueous potassium hydroxide solution gives a dihydroxy compound, while Z on similar treatment gives ethanal. Find out the molecular formula of X and give the structures of Y and Z.

**Solution**

Mass per cent of chlorine in the organic compound X

\[
\frac{M_{\text{Cl}}}{M_{\text{AgCl}}} \times \frac{m_{\text{AgCl}}}{m_{\text{compound}}} \times 100 = \frac{35.5}{143.5} \times \frac{2.90}{1.0} \times 100 = 71.21
\]

The ratios of atoms in the molecule of X are

\[
\text{C: H: Cl:} \quad \frac{24.24}{12} : \frac{4.04}{1} : \frac{71.21}{35.5} \quad \therefore \quad 2 : 4 : 2 : 1
\]

Empirical formula of X is CH₂Cl₂.

Since the isomer Y of the compound gives a dihydroxy compound on treating with aqueous KOH, it follows that the compound must contain two Cl atoms. Hence,

Molecular formula of X is C₂H₄Cl₂.

Its two isomers are \( \text{CH₃CHCl₂} \) and \( \text{CICH₂CH₂Cl} \).

The reaction are

\[
\begin{align*}
\text{CH₃CHCl₂} & \quad \xrightarrow{\text{aq. KOH}} \quad [\text{CH₃CH(OH)₂}] \quad \rightarrow \quad \text{CH₂CHO} \quad \text{ethanal} \\
\text{CICH₂CH₂Cl} & \quad \xrightarrow{\text{aq. KOH}} \quad \text{HOCH₂CH₂OH} \quad \text{ethylene glycol}
\end{align*}
\]

Match the entries given on the left with those given on the right.

(a) Cyclopropane, chlorine and light  
(b) Propanone and sodium bisulphite  
(c) Ethanal and Methanal  
(d) Benzene, nitric acid and sulphuric acid  
(e) Propene, hydrogen bromide and a peroxide catalyst  

(p) Electrophilic substitution  
(q) Homologous pair  
(r) Homolytic addition  
(s) Free radical substitution  
(t) Nucleophilic addition

Ans :

(a) – (s);  
(b) – (t);  
(c) – (q);  
(d) – (p);  
(e) – (r)
Match the entries given on the left with those given on the right.

(a) Pyrolysis of alkanes
(b) Benzene + Chloroethane
(c) CH₂COOC₂H₅ + NaOH
(d) Preparation of alkanes
(e) Phenol + CHCl₃ (NaOH)
(f) C₂H₅Br + alcKOH
(p) Elimination reaction
(q) Saponification
(r) Wurtz reaction
(s) Friedel-craft reaction
(t) Reimer-Tiemann reaction
(u) Cracking

Ans :
(a) - (u);
(b) - (s);
(c) - (q);
(d) - (r);
(e) - (t);
(f) - (p)

Identify the compound

A mixture of two aromatic compounds A and B was separated by dissolving in chloroform followed by extraction with aqueous KOH solution. The organic layer containing compound A, when heated with alcoholic solution of KOH produced a compound C (C₆H₅N) associated with an unpleasant odour. The alkaline aqueous layer on the other hand, when heated with chloroform and then acidified gave a mixture of two isomeric compounds D and E of molecular formula C₆H₄O₂. Identify the compounds A, B, C, D, and E and write their structures.

*Solution* We have

![Diagram showing the separation and reactions of compounds A and B](image)

The compound C is an isocyanide which is produced from a primary amine. Hence, the structures of C and A are

![Diagram showing the structures of C and A](image)

The compound B exhibits Reimer-Tiemann reaction. Thus, the compound B must be phenol. The reaction is
Rearrangement by migration of Bromine

Rearrangement, by migration of Br, of initially formed 1° radical into more stable 2° or 3° radical.
Chlorination of either n-propyl or isopropyl bromide gives 1-bromo-2-chloropropane.

\[
\begin{align*}
\text{CH}_3\text{CH}_2\text{CHBr} &\rightarrow \text{CH}_3\text{CH}_2\text{Cl} \\
\text{CH}_3\text{CHBrCH}_3 &\rightarrow \text{CH}_3\text{CHBrCH}_2\text{Cl} \\
\text{CH}_3\text{CH}_2\text{CHBr} &\rightarrow \text{CH}_3\text{CH}_2\text{Br}
\end{align*}
\]

Chlorination of either isobutyl or tert-butyl bromide gives 1-bromo-2-chloro-2-methylpropane.

\[
\begin{align*}
\text{(CH}_3\text{)}_2\text{CCHBr} &\rightarrow \text{(CH}_3\text{)}_2\text{CClBr} \\
\text{(CH}_3\text{)}_2\text{CBr} &\rightarrow \text{(CH}_3\text{)}_2\text{CCH}_2\text{Br}
\end{align*}
\]

Identify the Compound

An organic compound containing C, H and O exists in two isomeric forms A and B. A mass of 0.108 g of one of the isomers gives on combustion 0.308 g of CO₂ and 0.072 g of H₂O. A is insoluble in NaOH and NaHCO₃ while B is soluble in NaOH. A reacts with concentrated H₂SO₄ to give compounds C and D. C can be separated from D by the ethanolic AgNO₃ solution and D is soluble in NaOH. B reacts readily with bromine to give compound E of molecular formula, C₆H₅OBr₃. Identify A, B, C, D and E with justification and give their structures.

Solution

We have

\[
\text{Per cent of carbon in the compound } = \frac{M_C}{M_{\text{CO}_2}} \times \frac{m_{\text{CO}_2}}{m_{\text{compound}}} \times 100 = \left( \frac{12}{44} \right) \left( \frac{0.308}{0.108} \right) (100) = 77.78
\]

\[
\text{Per cent of hydrogen in the compound } = \frac{2M_H}{M_{\text{H}_2\text{O}}} \times \frac{m_{\text{H}_2\text{O}}}{m_{\text{compound}}} \times 100 = \left( \frac{2}{18} \right) \left( \frac{0.072}{0.108} \right) (100) = 7.41
\]

\[
\text{Per cent of oxygen in the compound } = 100 - (77.78 + 7.41) = 14.81
\]

The ratios of atoms in the compound are

\[
\text{C : H : O} = \frac{77.78}{12} : \frac{7.41}{1} : \frac{14.81}{16} = 6.48 : 7.41 : 0.926 = 7 : 8 : 1
\]

Hence, Empirical formula of the compound is C₇H₈O₇.

Since the isomer B on reacting with bromine water gives compound E (C₆H₅OBr₃), the molecular formula of A and B will be the same as the empirical formula derived above, since both contain the same number of carbon atoms. As E is obtained from B by the substitution of hydrogen with bromine and since there is high carbon content in B, the compounds A and B must be aromatic. Now, since compound A is insoluble in NaOH and NaHCO₃ and compound B is soluble in NaOH, it may be concluded that B is a phenolic compound and A is an ether. Hence, the structures of A and B are

\[
\begin{align*}
\text{(A)} &\quad \text{anisol} \\
\text{(B)} &\quad \text{m-cresol}
\end{align*}
\]

The bromination of B gives
Identify the compound

Basic volatile Nitrogen compound

A basic volatile nitrogen compound gave a foul smelling gas when treated with chloroform and alcoholic potash. A 0.295 g sample of the substance, dissolved in aqueous HCl, and treated with NaNO₂ solution at 0 °C liberated a colourless, odourless gas whose volume corresponded to 112 mL at STP. After the evolution of the gas was complete, the aqueous solution was distilled to give an organic liquid which did not contain nitrogen and which on warming with alkali and iodine gave a yellow precipitate. Identify the original substance. Assume that it contains one N atom per molecule.

Solution: Since the compound gives a foul smelling gas on treating with CHCl₃ and alcoholic KOH, the compound must be a primary amine.

\[
\text{RNH}_2 + \text{CHCl}_3 + 3\text{KOH} \rightarrow \text{RNC} + 3\text{KCl} + 3\text{H}_2\text{O} \tag{1}
\]

(alkyl isocyanide
(foul smelling gas)

Since the compound on treating with NaNO₂/HCl at 0 °C produces a colourless gas, the compound must be an aliphatic primary amine.

\[
\text{RNH}_2 + \text{HNO}_2 \rightarrow \text{ROH} + \text{N}_2 + \text{H}_2\text{O} \tag{2}
\]

Thus, the gas produced is nitrogen.

\[
\text{Amount of gas liberated} = \frac{112 \text{ mL}}{22400 \text{ mL mol}^{-1}} = \frac{1}{200} \text{ mol}
\]
From the above equation, it is obvious that

\[
\frac{2.295 \text{ g}}{M} = \frac{1}{200} \text{ mol}
\]

If \( M \) is the molar mass of \( RNH_2 \), then

\[
M = \frac{2.295 \times 200 \text{ g mol}^{-1}}{1} = 59 \text{ g mol}^{-1}.
\]

Thus, the molar mass of alkyl group R is (59 - 16) g mol\(^{-1}\), i.e., 43 g mol\(^{-1}\). Hence, R must be \( C_3H_7 \).

From Eq. (2), it is obvious that the liquid obtained after distillation is ROH. Since this gives yellow precipitate with alkali and iodine (iodoform test), it must contain \( CH_3\)\( -C- \) group. Hence, it is concluded that ROH is

\[
\begin{align*}
\text{CH}_3 & - \text{CH} - \text{CH}_3 \quad \text{Thus, the original compound is} \\
\text{OH} & \quad \text{CH}_3 - \text{CH} - \text{CH}_3
\end{align*}
\]

\[
\text{NH}_2
\]

isopropylamine

Match the entries given on the left with those given on the right.

(a) Lucas test
(b) Neutral FeCl\(_3\)
(c) Dye test
(d) Tollens test

(p) Phenol
(q) Glucose
(r) Tertiary alcohol
(s) Aniline

Ans : (a) - (r); (b) - (p); (c) - (s); (d) - (q)

Identify the compound

An organic compound \( A \), \( C_4H_{10} \), on treatment with dilute sulphuric acid containing mercuric sulphate gives a compound \( B \), which can also be obtained from a reaction of benzene with an acid chloride in the presence of anhydrous aluminium chloride. The compound \( B \), when treated with iodine in aqueous KOH, yields \( C \) and a yellow compound \( D \). Identify \( A \), \( B \), \( C \) and \( D \) with justification. Show how \( B \) is formed from \( A \).

**Solution**

The given reactions are

\[
\begin{align*}
\text{C}_4\text{H}_6 & \xrightarrow{\text{dil. H}_2\text{SO}_4} \text{ACl} \quad \text{B} \\
\text{B} & \xrightarrow{I_2/\text{KOH}} \text{C}_6\text{H}_6 + \text{acid chloride} \\
\text{C} + \text{D}
\end{align*}
\]

The reaction of \( B \) with \( I_2 \) in KOH is iodoform reaction. The compound \( D \) is iodoform, \( \text{CH}_3\text{I} \). The compound \( B \) must contain \( -\text{COCH}_3 \) group so as to exhibit iodoform reaction. Since \( D \) is obtained from benzene by Friedel-Crafts reaction, it is an aromatic ketone (\( \text{C}_6\text{H}_5\text{COCH}_3 \)). The compound \( C \) must be an acid.

The compound \( A \) may be represented as \( C_3H_7\text{C}_2H \). Since it gives \( C_3H_7\text{COCH}_3 \) on treating with dilute \( \text{H}_2\text{SO}_4 \) and \( \text{HgSO}_4 \), it must contain a triple bond \( (-\text{C}==\text{CH}) \) in the side chain. Hence, the given reactions may be represented as.
An organic compound E (C₅H₈) on hydrogenation gives compound F (C₅H₁₂). Compound E on ozonolysis gives formaldehyde and 2-keto-propanal. Deduce the structure of compound E.

**Solution**

Since there are four hydrogen atoms added in the reaction

\[ C₅H₈ + 4H → C₅H₁₂ \]

the compound E may contain two double bonds. The ozonolysis reaction is

\[ C₅H₈ + O₃ → HCHO + CH₃-C=CHO \]

Since there is no loss of carbon atoms in an ozonolysis reaction, probably 2 molecules of formaldehyde are formed. In 2-ketopropanal, -C=O and -CHO groups must have resulted due to the cleavage of double bonds. Hence, the net reaction can be explained as follows.

\[ \text{H₂C=O} + \text{O=CH--C--CH₃} \xrightarrow{O₃} \text{CH₂=CH--C--CH₃} \]

Hence, the compound E is 2-methyl-1, 3-butadiene.
Friedel Crafts Reaction

**Friedel-Crafts Reaction**

\[
\text{C}_6\text{H}_6 + \text{CH}_3\text{CH}_2\text{CH}_2\text{Cl} \xrightarrow{\text{AlCl}_3, -18^\circ\text{C to 80^\circ\text{C}}} \text{C}_6\text{H}_4\text{CH}_2\text{CH}_2\text{CH}_3 + \text{C}_6\text{H}_5\text{CHCH}_3
\]

\[
\text{C}_6\text{H}_6 + \text{CH}_3\text{CHCH}_2\text{Cl} \xrightarrow{\text{AlCl}_3, -18^\circ\text{C to 80^\circ\text{C}}} \text{C}_6\text{H}_5\text{C} - \text{CH}_3
\]

(only product)

\[
\text{C}_6\text{H}_6 + \text{CH}_3\text{CHCH}_2\text{OH} \xrightarrow{\text{BF}_3, 60^\circ\text{C}} \text{C}_6\text{H}_5\text{CCH}_2\text{CH}_3
\]

(only product)

Identify the compound

An Organic compound A has 76.6% C and 6.38% H (Aspirin)

An organic compound A has 76.6% C and 6.38% H. Its vapour density is 47. It gives characteristic colour with FeCl₃ solution. The compound A when treated with CO₂ and NaOH at 140°C under pressure gives B which on being acidified gives C. The compound C reacts with acetyl chloride to give D which is a well-known pain killer. Identify A, B, C and D and explain the reactions involved.

**Solution**

The ratios of atoms present in one molecule of A are

\[
\text{C} : \text{H} : \text{O} = 76.6 : 6.38 : 17.02 \quad : \quad 12 : 1 : 16 = 6.38 : 1 = 0.64 : 0.6 : 1
\]

Hence, empirical formula of A is C₆H₅O. Molar empirical formula mass of A = 94 g mol⁻¹. This tallies with the given molar mass (= 2 x 47 g mol⁻¹). Thus Molecular formula of A is C₆H₅O. Since, the compound A gives characteristic colour with FeCl₃, it must be a phenol.

The given reactions are

\[
\begin{align*}
\text{(A)} & \quad + \text{CO}_2 & \xrightarrow{\text{NaOH, 140°C, high pressure}} & \text{(B)} \\
\text{(B)} & \quad & \xrightarrow{\text{H}^+} & \text{(C)} \\
\text{(D)} & \quad & & \text{Aspirin (pain killer)}
\end{align*}
\]
Match the entries given on the left with those given on the right.

- **Friedel-Crafts**
  - oil
  - alkenes
- **Fermentation**
  - Lewis acid
  - soap
- **Dehydrohalogenation**
  - cuprous chloride
  - anhydrous AlCl₃
- **Sandmeyer**
  - yeast
  - chlorobenzene
- **Saponification**
  - alcoholic alkali
  - ethanol

Ans:

- Friedel-Crafts; Lewis acid; anhydrous AlCl₃
- Fermentation; yeast; ethanol
- Dehydrohalogenation; alcoholic alkali; alkenes
- Sandmeyer; cuprous chloride; chlorobenzene
- Saponification; oil; soap

Identify the compound

An organic compound A of molar mass 140.5 gm per mole has 68.32% Hydrogen

An organic compound A of molar mass 140.5 g mol⁻¹ has 68.32% C, 6.4% H and 25.26% Cl. Hydrolysis of A with dilute acid gives compound B, C₆H₅OH. Compound B can be oxidized under mild conditions to compound C, C₆H₅O. Compound C forms a phenylhydrazone D with PhNHNH₂ and gives a positive iodoform test. Deduce the structures of compounds A to D with proper reasoning.

**Solution**

The ratios of atoms in a molecule of A are

\[ \frac{C}{H/Cl} = \frac{68.32}{12} : \frac{6.4}{1} : \frac{25.26}{35.5} = 5.69 : 0.71 : 8 : 9 : 1 \]

Hence, the empirical formula of A is C₆H₅Cl. Molar empirical formula mass of A = 140.5 g mol⁻¹

Thus, the molecular formula of A is C₆H₅Cl.

The high content of carbon indicates the presence of aromatic (or benzene) ring in the molecule.

Since Cl atom in the compound A is easily replaced during hydrolysis of A with dilute acid, the Cl atom must be attached to the aliphatic portion of the molecule.

Since the compound C gives a positive iodoform test, it must contain—COCH₃ group.

Since the compound C is obtained by mild oxidation of B, the latter must be a secondary alcohol. Hence, the compound A also contains secondary chlorine atom. Consistent with this, the given reactions are as follows.
Question

Bleaching powder and bleach solution are produced on a large scale and used in several household products. The effectiveness of bleach solution is often measured by iodometry.

25 mL of household bleach solution was mixed with 30 mL of 0.50 M KI and 10 mL of 4 N acetic acid. In the titration of the liberated iodine, 48 mL of 0.25 N Na₂S₂O₃ was used to reach the end point. The molarity of the household bleach solution is

(a) 0.48 M  (b) 0.96 M  (c) 0.24 M  (d) 0.024 M

Bleaching powder contains a salt of an oxoacid as one of its components. The anhydride of that oxoacid is

(a) Cl₂O  (b) Cl₂O₇  (c) ClO₂  (d) Cl₂O₆

Solutions:

For Q.11, we may write

\[ \text{Household bleach} + 2 \text{ KI} \rightarrow \text{I}_2 + \text{products} \]

\[ \text{I}_2 + 2\text{Na}_2\text{S}_2\text{O}_3 \rightarrow \text{Na}_2\text{S}_2\text{O}_5 + 2\text{NaI} \]

Amount of Na₂S₂O₃ used = \( \nu M = (48 \times 10^{-3} \text{ L}) (0.25 \text{ mol} \text{ L}^{-1}) = 12 \times 10^{-3} \text{ mol} \)

Amount of I₂ generated = \( \frac{1}{2} \frac{12 \times 10^{-3} \text{ mol}}{2} = 6 \times 10^{-3} \text{ mol} \)

Assuming 1 mol of household bleach produces 1 mol I₂, we will have

Amount of household bleach in 25 mL solution = \( \frac{6 \times 10^{-3} \text{ mol}}{25 \times 10^{-3} \text{ L}} = 0.24 \text{ M} \)

For Q.12, we have

Bleaching powder contains Ca(OCl)Cl.

The oxoacid of this salt is HOCl. The formation of this acid through its anhydride is \( \text{Cl}_2\text{O} + \text{H}_2\text{O} \rightarrow 2\text{HOC}_\text{I} \) anhydride exoacid

Hence, we have

The choice (c) is correct.
The choice (a) is correct.

Match the compounds/ions in Column I with their properties/reactions in Column II.

<table>
<thead>
<tr>
<th>Column I</th>
<th>Column II</th>
</tr>
</thead>
<tbody>
<tr>
<td>(a) ( \text{C}_2\text{H}_4\text{CHO} )</td>
<td>(p) gives precipitate with 2,4-dinitrophenylhydrazine</td>
</tr>
<tr>
<td>(b) ( \text{CH}_3\text{C}==\text{CH} )</td>
<td>(q) gives precipitate with AgNO₃</td>
</tr>
<tr>
<td>(c) ( \text{CN}^- )</td>
<td>(r) is a nucleophile</td>
</tr>
<tr>
<td>(d) I⁻</td>
<td>(s) is involved in cyanohydrin formation</td>
</tr>
</tbody>
</table>

Ans:

(a) \( \neg (p), (q), (s) \);  \( (b) \neg (q) \);  \( (c) \neg (q), (r), (s) \);  \( (d) \neg (q) \)
In decreasing order of oxidation state of Nitrogen

Which ordering of compounds is according to the decreasing order of the oxidation state of nitrogen?
(a) \( \text{HNO}_3, \text{NO}, \text{NH}_4\text{Cl}, \text{N}_2 \)  
(b) \( \text{HNO}_3, \text{NO}, \text{N}_2, \text{NH}_4\text{Cl} \)
(c) \( \text{HNO}_3, \text{NH}_4\text{Cl}, \text{NO}, \text{N}_2 \)  
(d) \( \text{NO}, \text{HNO}_3, \text{NH}_4\text{Cl}, \text{N}_2 \)

**Solution:**
The oxidation states of nitrogen in the given compounds are as follows.
\[ \text{HNO}_3 : +1 + x + 3 (-2) = 0 \quad \Rightarrow \quad x = +5 \]
\[ \text{NO} : \quad x + (-2) = 0 \quad \Rightarrow \quad x = +2 \]
\[ \text{NH}_4\text{Cl} : x + 4 (+1) + (-1) = 0 \quad \Rightarrow \quad x = -3 \]
\[ \text{N}_2 : \quad 2(x) = 0 \quad \Rightarrow \quad x = 0 \]

Thus, the decreasing oxidation numbers of nitrogen is \( \text{HNO}_3, \text{NO}, \text{N}_2 \) and \( \text{NH}_4\text{Cl} \).

Therefore, the **choice (b)** is correct.

---

**Gyan Question**

The kinetic energy of an electron in the second Bohr orbit

The kinetic energy of an electron in the second Bohr orbit of a hydrogen atom \((a_0 \text{ is Bohr radius})\) is
(a) \( \frac{\hbar^2}{4\pi^2 m a_0^2} \)  
(b) \( \frac{\hbar^2}{16\pi^2 m a_0^2} \)  
(c) \( \frac{\hbar^2}{32\pi^2 m a_0^2} \)  
(d) \( \frac{\hbar^2}{64\pi^2 m a_0^2} \)

**Solution:**
Bohr model of an atom satisfies the following two requirements.
- Equality of centripetal and centrifugal forces, i.e.
  \[ \frac{(Ze)(e)}{(4\pi\epsilon_0)r^2} = \frac{ma^2}{r} \]
- Quantization of angular momentum, i.e.
  \[ mv\rho = n \left( \frac{\hbar}{2\pi} \right) \]

Eliminating \( \rho \) in these two expressions, we get
\[ r = n^2 \left[ \frac{\hbar^2}{4\pi^2 m (Ze^2 / 4\pi\epsilon_0)} \right] = \frac{n^2}{Z} a_0 \]

where \( a_0 \) is the Bohr radius. The kinetic energy of the electron in Bohr orbit of an atom is
\[ KE = \frac{1}{2} mv^2 = \frac{1}{2} \left[ \frac{n}{mr} \left( \frac{\hbar}{2\pi} \right) \right]^2 = \frac{1}{2} \left[ \frac{n}{m(\pi^2 a_0^2 / Z)} \left( \frac{\hbar}{2\pi} \right) \right]^2 = \frac{Z^2 (\hbar^2)}{n^2 (8\pi^2 ma_0^2)} \]

For the second Bohr orbit of hydrogen atom, \( Z = 1 \), and \( n = 2 \). Hence
\[ KE = \frac{1}{32} \left( \frac{\hbar^2}{\pi^2 ma_0^2} \right) \]

Therefore, the **choice (c)** is correct.
Question on Aldol reaction

The number of aldol reaction(s) that occurs in the given transformation

\[ \text{CH}_3\text{CHO} + 4\text{HCHO} \xrightarrow{\text{conc. aq. NaOH}} \text{HO-} - \text{OH} \]

is

(a) 1  (b) 2  (c) 3  (d) 4

**Solution:**

The given reaction may be formulated as follows.

- **First aldol condensation**
  \[ \text{HCHO} + \text{HCHO} \xrightarrow{\text{OH}^-} \text{H-CH}_2\text{CHO} \]

- **Second aldol condensation**
  \[ \text{HCHO} + \text{HOC}_2\text{H}_2\text{CHO} \xrightarrow{\text{OH}^-} \text{H-CH}_2\text{CH}_2\text{CHO} \]

- **Third aldol condensation**
  \[ \text{HCHO} + \text{HOC}_2\text{H}_2\text{CHO} \xrightarrow{\text{OH}^-} \text{H-CH}_2\text{CH}_2\text{CHO} \]

- **Cannizzaro reaction**
  \[ \text{HCHO} + \text{HOC}_2\text{H}_2\text{CHO} \xrightarrow{\text{OH}^-} \text{HOOC}^- + \text{HOC}_2\text{H}_2\text{CHO} \]

There are three aldol condensations and one Cannizzaro reaction. Therefore, the choice (c) is correct.

An organic compound undergoes first order decomposition

An organic compound undergoes first-order decomposition. The time taken for its decomposition to 1/8 and 1/10 of its initial concentration are \( t_{1/8} \) and \( t_{1/10} \) respectively. What is the value of \( (t_{1/8}/t_{1/10}) \)? (log 2 = 0.3.)

**Solution:**

For first-order decomposition of \( A \), the rate law is \( \ln ([A]/[A]_0) = -kt \)

Hence \( \ln(1/8) = -k t_{1/8} \) and \( \ln(1/10) = -k t_{1/10} \)

Thus \( \frac{\ln(1/8)}{\ln(1/10)} = \frac{t_{1/8}}{t_{1/10}} \) or \( \log 8 = \frac{t_{1/8}}{t_{1/10}} \)

Hence \( (t_{1/8}/t_{1/10}) = \log 8 = \log 2^3 = 3 \log 2 = 3 \times 0.3 = 0.9 \) or \( 10(t_{1/8} / t_{1/10}) = 10 \times 0.9 = 9 \)

Therefore, the answer is 9.
Allene has sp hybridization

In allene \((C_3H_4)\), the type(s) of hybridization of the carbon atom is (are)

(a) \(sp\) and \(sp^3\)  
(b) \(sp\) and \(sp^2\)  
(c) \(sp^3\) only  
(d) \(sp^2\) and \(sp^3\)

**Solution:**

The structure of allene is

In this molecule, carbon atoms 1 and 3 are \(sp^2\) hybridized while the carbon atom 2 is \(sp\) hybridized. Therefore, the choice (b) is correct.

Number of chiral carbon and optically active products

The number of optically active products obtained from the complete ozonolysis of the given compound

\[ \text{CH}_3\text{-CH=CH}\text{-C=}\text{-CH=CH}\text{-CH=CH-CH}_3 \]

(a) 0  
(b) 1  
(c) 2  
(d) 4

**Solution:**

The ozonolysis of the compound is as follows:

\[ \text{CH}_3\text{-CH=CH}\text{-C=}\text{-CH=CH}\text{-CH=CH-CH}_3 \rightarrow \text{CH}_3\text{CHO} + \text{OCH=CHO} + \text{OCH-CH}_3 \]

None of the products will be optically active. Therefore, the choice (a) is correct.
Carboxylic functional group is present in aspirin.

The carboxylic functional group (−COOH) is present in
(a) picric acid  (b) barbituric acid  (c) ascorbic acid  (d) aspirin

**Solution:**
The structures of the given compounds are as follows.

- Picric acid
- Barbituric acid
- Ascorbic acid
- Aspirin

Therefore, the **choice (d)** is correct.

Identify the compound

In the following reaction sequence, the compound J is an intermediate.

\[
\begin{align*}
  \text{I} & \xrightarrow{\text{CH}_3\text{CO}_2\text{O}} \text{CH}_3\text{COONa} & \xrightarrow{\text{J}} & \text{H}_2\text{Pd/C} & \xrightarrow{\text{J}} & \text{K} \\
  \text{H}_2\text{O}_2 & \xrightarrow{\text{NaHCO}_3} & \text{Na}_2\text{CO}_3
\end{align*}
\]

J(C₇H₇O₂) gives effervescence on treatment with NaHCO₃ and positive Baeyer’s test.

Q. The compound K is

(a)  ![Option A](image1)
(b)  ![Option B](image2)
(c)  ![Option C](image3)
(d)  ![Option D](image4)

Q. The compound I is

(a)  ![Option A](image5)
(b)  ![Option B](image6)
(c)  ![Option C](image7)
(d)  ![Option D](image8)
Perkin Condensation

Solutions:
The compound J must contain a —COOH group as it gives effervescence with NaHCO₃. Also, it is an unsaturated compound as it gives positive Baeyer’s test (decolourization of pink colour of alkaline KMnO₄). Since the compound J is obtained by treating the compound I with (CH₃CO)₂O and CH₃COONa, and more over the compound J seems to be aromatic (high carbon content), the compound J amongst the choices given in Q.14 seems to be benzaldehyde as it shows Perkin condensation shown in the following

\[
\text{CHO} + (\text{CH}_3\text{CO})_2\text{O} \xrightarrow{\Delta} \text{CH}_3\text{COONa} \rightarrow \text{CH}==\text{CHCOOH}
\]

\(\alpha, \beta\)-unsaturated carboxylic acid

The conversion J to K is as follows.

\[\text{CHO} \xrightarrow{\text{H}_3\text{Pd/C}} \text{CH}_3\text{CH}_2\text{COOH} \xrightarrow{\text{SOCl}_2} \text{CH}_3\text{CH}_2\text{CHO} \xrightarrow{\text{ethyl acetate, \text{AlCl}_3}} \text{K} \]

Hence, we have

The choice (c) is correct.
The choice (a) is correct.

Question on isomers

Which of the given statement(s) about N, O, P and Q with respect to M is(are) correct?

(a) M and N are non-mirror image stereoisomers.
(b) M and O are identical
(c) M and P are enantiomers
(d) M and Q are identical

Solution:
First of all, we may draw Fischer projections of the given compounds.
Aldohexose exists in D configuration

When the following aldohexose exists in D-configuration, the total number of stereoisomers in its pyranose form is

CHO
CH₂
CHOH
CHOH
CHO
CH₂OH

**Solution:**

In D-configuration, the hydroxyl group at the asymmetric carbon placed at the bottom of Fischer projection lies to the right of the straight skeleton. Thus, we will have
There are four chiral carbon atoms in the pyranose form of the given aldohexose. Thus, there will be $16 \ (= 2^4)$ stereoisomers, out of which 8 are of D-configurations (CH$_2$OH group above the ring) and 8 are of L-configurations (CH$_3$OH group below the ring). Therefore, the correct answer is 8.

Peptides

The substituents $R_1$ and $R_2$ for nine peptides are listed in the table given below. How many of these peptides are positively charged at pH = 7.0?

<table>
<thead>
<tr>
<th>Peptide</th>
<th>$R_1$</th>
<th>$R_2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>H</td>
<td>H</td>
</tr>
<tr>
<td>II</td>
<td>H</td>
<td>CH$_3$</td>
</tr>
<tr>
<td>III</td>
<td>CH$_3$COOH</td>
<td>H</td>
</tr>
<tr>
<td>IV</td>
<td>CH$_3$CONH$_2$</td>
<td>(CH$<em>2$</em>)$_2$NH$_2$</td>
</tr>
<tr>
<td>V</td>
<td>CH$_3$CONH$_2$</td>
<td>CH$_2$CONH$_2$</td>
</tr>
<tr>
<td>VI</td>
<td>(CH$<em>2$</em>)$_2$NH$_2$</td>
<td>(CH$<em>2$</em>)$_2$NH$_2$</td>
</tr>
<tr>
<td>VII</td>
<td>CH$_3$COOH</td>
<td>CH$_2$CONH$_2$</td>
</tr>
<tr>
<td>VIII</td>
<td>CH$_3$OH</td>
<td>(CH$<em>2$</em>)$_2$NH$_2$</td>
</tr>
<tr>
<td>IX</td>
<td>(CH$<em>2$</em>)$_2$NH$_2$</td>
<td>CH$_3$</td>
</tr>
</tbody>
</table>

Solution

In general, the pH of the solution at which amino acids exist as zwitterion follows the order:

- Acidic side chain < neutral chain < basic side chain

<table>
<thead>
<tr>
<th>pH</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>&lt;</td>
</tr>
<tr>
<td>5.5</td>
<td>&lt;</td>
</tr>
<tr>
<td>9.0</td>
<td>&gt;</td>
</tr>
</tbody>
</table>

This pH is known as isoelectric point.

At pH = 7, the acidic side chain (for which isoelectric point < 7) exists as a negatively-charged species (e.g., —COO$^-$) and the basic side chain (for which isoelectric point > 7) exists as a positively charged species (e.g., —NH$_3^+$). Since peptides IV, VI, VIII and IX contain —NH$_2$ group in $R_1$ or/and $R_2$ group(s), these are expected to exist as positively-charged species.

Therefore, the correct answer is 4.
Try to figure out what sequence is depicted

neopentane < isopentane < n-pentane. A branched chain isomer has a lower boiling point than a straight chain isomer. The more numerous the branches, the lower the boiling point. The branching lowers the boiling point for all families of organic compounds. Branching causes the shape of molecule to approach towards a sphere and thus surface area decreases, with the result that the intermolecular forces become weaker and are overcome at a lower temperature.

n-butyl alcohol < isobutyl alcohol < sec-butyl alcohol < tert-butyl alcohol. Polarity of O—H bond increases in the same order.

(CH₃)₂CCOOH < (CH₃)₂CHCOOH < CH₃CH₂COOH < CH₃COOH < HCOOH

The presence of bulky groups near the site of reaction, whether in the alcohol or in the acid, slows down esterification as well as de-esterification (hydrolysis).

(CH₃)₂CCOOCH₃ < (CH₃)₂CHCOOCH₃ < CH₃COOCH₃ < HCOOCH₃
CH₃COOC(CH₃)₂ < CH₃COOCH(CH₃)₂ < CH₃COOC₂H₅ < CH₃COOCH₃

Try to figure out the sequences

adipic acid < succinic acid < malonic acid < oxalic acid

Acidity decreases with increase in the intervening CH₂ groups.

iso-propanol < n-butane < n-butyl chloride < n-butanol
chlorobenzene < benzene < toluene < methoxybenzene
Decreasing order of reactivity towards alcoholic silver nitrate:
2-bromo-1-phenylethene, α-phenylethyl bromide, β-phenylethyl bromide

Increasing order of reactivity towards aqueous NaOH:
chlorobenzene, m-chloronitrobenzene, o-chloronitrobenzene, 2,4-dinitrochlorobenzene,
2,4,6-trinitrochlorobenzene

Increasing reactivity towards HCN: CH₃CHO, CH₃COCH₃, HCHO, C₂H₅COCH₃
Increasing basicity: p-toluidine, N, N-dimethyl-p-toluidine, p-nitroaniline, aniline.
Increasing ease of hydrolysis: CH₃COOC₂H₅, CH₃COCl, (CH₃CO)₂O, CH₃CONH₂
Increasing order of acid strength:
CICH₂COOH, CH₃CH₂COOH, CICH₂CH₂COOH, (CH₃)₂CHCOOH, CH₃COOH

Increasing reactivity in nucleophilic substitution reactions: CH₃F, CH₃I, CH₃Br, CH₃Cl

The major product H in the given reaction sequence

\[
\text{CH}_3-\text{CH}_2-\text{CO}-\text{CH}_3 \xrightarrow{\text{CN}^-/\text{H}_2\text{SO}_4\text{, Heat}} \text{H}
\]

is
(a) \(\text{CH}_3-\text{CH}=\text{C}-\text{COOH}\)
(b) \(\text{CH}_3-\text{CH}=\text{C}-\text{CN}\)
(c) \(\text{CH}_3-\text{CH}_2-\text{C}=\text{COOH}\)
(d) \(\text{CH}_3-\text{CH}=\text{C}=\text{CO}\text{-NH}_2\)

**Solution:**
The first reaction is nucleophilic addition reaction across the \(-\text{C}=\text{O}\) bond.

In the second reaction, \(-\text{CN}\) is hydrolysed to \(-\text{COOH}\). The resultant molecule undergoes dehydration on heating.

Therefore, the choice (a) is correct.
Explain these by solving in right order:

- **Increasing reactivity towards $S_1$ solvolysis:**
  benzyl chloride, $p$-chlorobenzyl chloride, $p$-methoxybenzyl chloride, $p$-methylbenzyl chloride, $p$-nitrobenzyl chloride,

- **Increasing order of reactivity towards elimination by alcoholic KOH:**
  1-phenyl-2-bromopropane, 1-phenyl-3-bromopropane

- **Decreasing order of reactivity towards aqueous HBr:** Isomeric pentyl alcohols

- **Increasing order of reactivity towards aqueous HBr:**
  1-phenyl-1-propanol, 3-phenyl-1-propanol, 1-phenyl-2-propanol

- **Decreasing order of reactivity towards aqueous HBr:**
  benzyl alcohol, $p$-cyanobenzyl alcohol, $p$-hydroxybenzyl alcohol

- **Increasing order of reactivity towards aqueous HBr:**
  benzyl alcohol, diphenylmethanol, methanol and triphenylmethanol

- **Decreasing order of reactivity towards bromination:**
  anisole, benzene, toluene, chlorobenzene, nitrobenzene, phenol

- **Increasing order of reactivity towards bromination:**
  hydroquinone, $p$-methoxyphenol, $p$-methylphenol, $p$-chlorophenol, $p$-nitrophenol, sym-trihydroxybenzene

- **Decreasing order of acidity of carboxylic acids:**
  butanoic acid, 2-bromobutanoic acid, 3-bromobutanoic acid, 4-bromobutanoic acid

- **Decreasing reactivity towards $S_2$I substitution:**
  1-chloropropene 3-chloropropene, $n$-propylchloride

- **Decreasing acidity:** $\text{H}_2\text{O}$, $\text{HC}==\text{CH}$, $\text{NH}_3$, $\text{RH}$, $\text{ROH}$

- **Decreasing basicity:** $\text{R}^-$, $\text{HC}==\text{C}^-$, $\text{NH}_2\text{OH}^-$, $\text{OR}^-$

- **Decreasing order of reactivity towards the addition of HCl:**
  styrene, $p$-chlorostyrene, $p$-methylstyrene, $p$-nitrostyrene

- **Decreasing order of reactivity towards dehydration:**
  $\alpha$-phenyl ethyl alcohol, $\alpha$-($p$-nitrophenyl) ethyl alcohol, $\alpha$-($p$-aminophenyl) ethyl alcohol
Various Increasing Properties

**Increasing stability of free radicals:** $\cdot$CH$_3$, 1°, 2°, 3°, allyl, vinyl

**Increasing stability of carbocation:** CH$_3^+$, 1°, 2°, 3°

**Increasing enthalpy of reaction:**

\[
\begin{align*}
\text{CH}_3\text{Br} & \rightarrow \text{CH}_3^+ + \text{Br}^- & \Delta H_1 \\
\text{CH}_3\text{CH}_2\text{Br} & \rightarrow \text{CH}_3\text{CH}_2^+ + \text{Br}^- & \Delta H_2 \\
\text{CH}_3\text{CHCH}_3 & \rightarrow \text{CH}_3\text{CHCH}_3^+ + \text{Br}^- & \Delta H_3 \\
\text{CH}_3\text{—CH—CH}_3 & \rightarrow \text{CH}_3\text{—CH—CH}_3^+ + \text{Br}^- & \Delta H_4
\end{align*}
\]

**Increasing order of reactivity towards S$_N$2 displacement:**

1-bromopentane, 2-bromopentane, 2-bromo-2-methylbutane

The compound that undergoes decarboxylation most readily under mild condition is

(a) \[
\text{COOH} \quad \text{CH}_2\text{COOH}
\]
(b) \[
\text{COOH}
\]
(c) \[
\text{COOH}
\]
(d) \[
\text{CH}_3\text{COOH}
\]

**Solution:**

β-Ketocarboxylic acid is unstable acid. It readily undergoes decarboxylation through a cyclic transition state.

Therefore, the **choice** (b) is correct.

A compound contains 88.89% C and 11.1% H. It gives white precipitate with ammoniacal silver nitrate. The compound is

(a) C$_6$H$_5$C ≡ CH (b) C$_4$H$_4$C ≡ CH (c) C$_6$H$_5$C ≡ CH (d) C$_8$H$_8$C ≡ CH

Ans:

(c) C$_6$H$_5$C ≡ CH
More the number of electron withdrawing group stronger is the acid

\[ \text{Cl}_2\text{CCOOH} > \text{Cl}_2\text{CHCOOH} > \text{ClCH}_2\text{COOH} > \text{CH}_3\text{COOH} \]

The more the number of electron-withdrawing group, the stronger the acid.

Try to figure out what sequence is depicted

\[ \text{FCH}_2\text{COOH} > \text{ClCH}_2\text{COOH} > \text{BrCH}_2\text{COOH} > \text{ICH}_2\text{COOH} \]

The more the electronegativity of halogen, the stronger the acid.

\[ \text{CH}_3\text{COOH} < \text{ClCH}_2\text{CH}_2\text{COOH} < \text{ClCH}_2\text{COOH} \]

\[ \text{HO} - \overset{\text{COOH}}{\text{C}} < \overset{\text{H}}{\text{C}} - \overset{\text{COOH}}{\text{C}} < \overset{\text{Br}}{\text{C}} - \overset{\text{COOH}}{\text{C}} < \overset{\text{Cl}}{\text{C}} - \overset{\text{COOH}}{\text{C}} < \overset{\text{O}_2\text{N}}{\text{C}} - \overset{\text{COOH}}{\text{C}} \]

\[ \text{H}_2\text{O} < \text{C}_2\text{H}_5\text{OH} < \text{C}_2\text{H}_5\text{COOH} < \text{HCOOH} < \text{HCl} \]

phenol < \text{p-nitrophenol} < \text{H}_2\text{CO}_3 < \text{C}_2\text{H}_5\text{COOH} \]

\[ \text{C}_6\text{H}_5\text{NH}_2 < \text{C}_6\text{H}_5\text{NHCH}_3 < \text{NH}_3 < \text{CH}_3\text{NH}_2 < (\text{CH}_3)_2\text{NH} \]

\[ (\text{CH}_3)_3\text{N} < \text{CH}_2\text{NH}_2 < (\text{CH}_3)_2\text{NH} \] (\text{CH}_3)_3\text{N} is the weakest because of steric factors.

1-butanol < 2-butanol < 2-methyl-2-propanol. A tertiary alcohol reacts immediately, a secondary alcohol reacts within five minutes and a primary alcohol does not.

1-butanol < 2-butanol < 1-butanol. Reactivity of ROH is CH₃OH ≈ 1° > 2° > 3°.

An organic compound A contains 49.32% C, 9.59% H and 19.18% N and rest oxygen. The compound A on boiling with NaOH gives nitrogen free carboxylic acid whose silver salt contains 59.67% Ag. The compound A is

(a) \( \text{CH}_3\text{CONH}_2 \)  \hspace{1cm} (b) \( \text{C}_2\text{H}_5\text{CONH}_2 \)  \hspace{1cm} (c) \( \text{C}_3\text{H}_7\text{CONH}_2 \)  \hspace{1cm} (d) \( \text{C}_4\text{H}_9\text{CONH}_2 \)

Ans:

An organic compound A contains 49.32% C, 9.59% H and 19.18% N and rest oxygen. The compound A on boiling with NaOH gives nitrogen free carboxylic acid whose silver salt contains 59.67% Ag. The compound A is

(a) \( \text{CH}_3\text{CONH}_2 \)  \hspace{1cm} (b) \( \text{C}_2\text{H}_5\text{CONH}_2 \)  \hspace{1cm} (c) \( \text{C}_3\text{H}_7\text{CONH}_2 \)  \hspace{1cm} (d) \( \text{C}_4\text{H}_9\text{CONH}_2 \)

Hence \( \frac{108}{M_R + 44 + 108} = 0.5967 \). This gives \( M = 29 \) i.e. \( R = \text{C}_2\text{H}_5 \).

Hence, the compound is \( \text{C}_2\text{H}_5\text{CONH}_2 \).
Try to figure out what sequence is depicted

\[
\begin{align*}
\text{CH}_3\text{CHO} & < \text{CH}_2\text{COCH}_3 < \text{CH}_3\text{COCH}_2\text{CHO} < \text{CH}_2\text{COCH}_2\text{COCH}_3 \\
\text{NO}_2 & > \text{F} > \text{Cl} > \text{OCH}_3 > \text{CH}_3 > \text{C}_6\text{H}_5 > \text{CH}_3 > \text{C}_2\text{H}_5 > (\text{CH}_3)_2\text{C}.
\end{align*}
\]

The smaller the alkyl group, the more reactive the carbonyl group.

\[
\text{CH}_2=\text{CH}_2 < \text{CH}_3\text{CH}=\text{CHCH}_3 < (\text{CH}_3)_2\text{C}=\text{CH}_2
\]

The more stable the intermediate carbocation, the greater the reactivity.

\[
\begin{align*}
\text{CH}_2=\text{CH}_2\text{H}_3 & < \text{CH}_3\text{CH}=\text{CHCH}_3 < \text{CH}_2=\text{CH}-\text{CH} & & \text{CH}_2 < \text{CH}_2=\text{CH}-\text{CH} & & \text{CH}_2=\text{CH}-\text{CH} & & \text{CH}_2\\
& & & & & & & & & & & & \text{CH}_3 & \text{CH}_3
\end{align*}
\]

Conjugated dienes form the more stable allyl carbocations and are thus more reactive than alkenes. Alkyl groups on the unsaturated carbon atoms increase reactivity.

\[
\begin{align*}
\text{C}_2\text{H}_4\text{CH}_3 & < \text{C}_6\text{H}_5\text{CH}_2\text{Cl} < \text{C}_6\text{H}_5\text{CHCl}_2 < \text{C}_6\text{H}_5\text{CCl}_3 \\
\text{tert-butanol} & < \text{sec-butanol} < \text{n-butanol} < \text{CH}_3\text{OH}.
\end{align*}
\]

Alkyl group makes an alcohol less acidic. Bigger the alkyl group, the less acidic the alcohol. Methanol is the strongest and terytial alcohols are the weakest.

\[
\begin{align*}
(\text{CH}_3)_2\text{CHCOOH} & < \text{C}_2\text{H}_5\text{COOH} < \text{CH}_3\text{COOH} < \text{C}_6\text{H}_5\text{COOH} < \text{HCOOH} < \text{CH}_2\text{COOH}
\end{align*}
\]

An aromatic compound contains 69.4% C and 5.8% H

An aromatic compound contains 69.4% C and 5.8% H. A sample of 0.3 g of this compound give ammonia which neutralizes 25 mL of 0.05 M \(\text{H}_2\text{SO}_4\). The empirical formula of the compound is

\[
\begin{align*}
(\text{a}) & \quad \text{C}_6\text{H}_5\text{NO} & \quad \text{(b}) & \quad \text{C}_6\text{H}_6\text{NO} & \quad \text{(c}) & \quad \text{C}_6\text{H}_7\text{NO} & \quad \text{(d}) & \quad \text{C}_6\text{H}_8\text{NO}
\end{align*}
\]

Ans:

\[
\begin{align*}
\text{Amount of } \text{H}_2\text{SO}_4 & \text{ neutralized} = (25 \times 10^{-3} \text{ L})(0.05 \text{ M}) = 1.25 \times 10^{-3} \text{ mol} \\
\text{The neutralization reaction is} & \quad 2\text{NH}_3 + \text{H}_2\text{SO}_4 \rightarrow (\text{NH}_4)_2\text{SO}_4 \\
\text{Amount of } \text{NH}_3 & \text{ evolved} = 2 \times 1.25 \times 10^{-3} \text{ mol} = 2.5 \times 10^{-3} \text{ mol} \\
\text{Mass of } \text{N} & \text{ in the compound} = (2.5 \times 10^{-3} \text{ mol})(14 \text{ g mol}^{-1}) = 0.035 \text{ g} \\
\text{Per cent of } \text{N} & \text{ in the compound} = \frac{0.035}{0.3} \times 100 = 11.67 \\
\text{Per cent of } \text{O} & \text{ in the compound} = 100 - (69.4 + 5.8 + 11.67) = 13.13 \\
\text{Ratio of atoms in the compound is} & \quad \text{C} : \text{H} : \text{N} : \text{O} :: 69.4 : 5.8 : 11.67 : 13.13 :: 5.78 : 5.8 : 0.83 : 0.82 :: 7 : 7 : 1 : 1 \\
\text{Hence, empirical formula:} & \quad \text{C}_6\text{H}_7\text{NO} \\
\text{Alternatively, calculate per cent of } \text{C} & \text{ in the given choices which comes out to be} \quad (\text{a}) \quad 0.55, \quad (\text{b}) \quad 0.69, \quad (\text{c}) \quad 0.58 \\
\text{and} & \quad (\text{d}) \quad 0.65 \text{ only for choice (b), the answer tallies.}
\end{align*}
\]
Zwitter ions - The Hydrogen atom (rather ion) moves to different positions depending on the pH (So can have a positive charge at some position, or a negative charge at some other position, depending on the pH).

Electrophoresis - is a method to confirm if a positive charge is present or a negative charge is present in the ion.

Iso - Electric point - the pH at which the ion (molecule) does not migrate to any electrodes.

What happens if oxalic acid is heated with conc sulphuric acid?

We get Carbon monoxide

\[
\text{COOH} + (\text{H}_2\text{SO}_4)(\text{l}) \rightarrow \text{H}_2\text{O} + \text{CO}_2(\text{g}) + \text{CO}(\text{g}) + (\text{H}_2\text{SO}_4)(\text{l})
\]

Important order and facts of organic chemistry

1. RCOCl > RCOCOR > RCOOR > RCONH₂ Nucleophilic substitution reaction.

2. HI > HBr > HCl > RCOOH > C₆H₅OH > H₂O > CH₃CH > NH₃ (Acidic nature).
3. $\text{CCl}_3\text{CHO} > \text{HCHO} > \text{CH}_3\text{CHO} > \text{CH}_3\text{COCH}_3$ Nucleophilic addition reaction.

4. $\text{CH}_2 = \text{CH}_2 > \text{CH} \equiv \text{CH} > \text{C}_2\text{H}_4$ Electrophilic addition reaction.

5. Substitution Reaction

6. Nucleophilic Substitution Reaction

7. Nucleophilic Substitution Reaction

8. (Carbocation stability)

9. (Carbanion stability)

10. (Stability)

11. (Heat of Hydration)

12. (Basic strength)

13. (Basic strength)

14. (Selectivity for halogenation)

15. Halogenation of alkenes by cyclic halonium state, so anti attack takes place.

16. Hydroboration followed by oxidation is always anti markownikoff’s addition due to steric effect.

17. Oximercuration - demercuration is markownikoff’s addition of water because some carbocation character in cyclic mercurium state.

18. $\text{CHCl}_3$ in the presence of strong bases forms biradical : $\text{CCl}_2$ which undergo addition with double or triple bonds.

19. When conjugated diene reacts with alkene or alkyne it is known as diel’s elder synthesis.

20. Ozonolysis of cyclo alkene forms one mole dialdehyde while ozonolysis of cyclo alkydienes forms two moles of dialdehyde.

21. Ozonolysis with $(\text{CH}_3)_2\text{S}$ is known as reductive ozonolysis.

22. Hydration of alkyne occur’s in $\text{HgSO}_4$ and dil $\text{H}_2\text{SO}_4$. 
23. 1-alkynes forms ppt with Ag(NH₃)₂⁺ and Cu(NH₃)₂⁺.

24. Cis-2-butene reacts with Br₂ to forms dl(±) pair of enantiomers of 2,3-dibromobutane while in case of trans-2-butene forms meso-2,3-dibromo butane due to anti addition always.


26. Chloral reacts with chloro benzene in con. H₂SO₄ to form insectiside DDT.

27. NBS is used for free radical allylation.

28. Rate for S⁻¹ reaction is 3° > 2° > 1° in protic polar solvent.

29. Rate for S⁻² reaction is 1° > 2° > 3° in polar aprotic solvent like DMSO, DMF, HMPT.

30. Chemical reactions like Hoffmann carbylamine and Reimer Tiemann’s reaction active species is biradical CCl₂.

31. If cyclo 1,3-penta diene reacts with CHCl₃ and potassium tert. butoxide to form chlorobenzene.

32. Alkyl halides reacts with AgCN to form isocyanides due to ambident nature of nucleophile, other ambident nucleophiles are NO₂⁻ and SO₃²⁻.

33. In dehydration of alcohols active species is carbocation so rearrangement occurs like hydride shift or alkyl shift.

34. Dehydration of cyclobutyl methyl alcohol ring expansion takes place, formation of cyclo pentene occurs.

35. In esterification where acid reacts with alcohol to form ester, -OH given by acid while -H by alcohol

\[
\text{CH}_3\text{COOH} + \text{C}_2\text{H}_5\text{OH} \xrightleftharpoons{\text{H}^+} \text{CH}_3\text{COOC}_2\text{H}_5 + \text{H}_2\text{O}
\]

36. Ether’s reacts with HI to form alcohol and halide where fission of lower ether by S⁻⁲ mechanism while higher ethers like ter. butyl methyl ether or alkyl methyl ether by S⁻¹ mechanism.

37. Quantitative estimation of ethers is done by ziesal’s method.

38. If unsym. cyclic ether undergo fission it depends upon medium weather it is acid or basic like in acidic medium some character of carbocation so nucleophile goes to carbon where more alkyl groups are there while reverse in basic medium due to steric factor.

39. Aldehydes are reducing agent while ketones are not.

40. Aldehydes and ketones are separated by tollen’s reagent.

41. Carbonyl and noncarbonyl are separated by sodium bi sulphite and bradye’s reagent.

42. As the size of alkyl group increases steric hindrance comes into play, reactivity towards nucleophilic addition decreases.

43. Aldehydes with hydrogen atom in the presence of dil base undergo enolization and form ∞.
44. If there is two-CHO group with \( \equiv \)hydrogen atom to form cyclic intra aldol product.

45. Aldehydes without -hydrogen atom in the presence of con. alkali to form each molecule of acid and alcohol by hydride active species.

46. Glyoxal reacts with con. KOH to form glycolate ion by Intra Cannizaro’s.

47. Pinacol pinacolone type reactions involve protonation, deprotonation and alkyl shift.

48. Aldol, Perkin, reformatsky and knovengel’s reactions are classified as carbanian active reaction.

49. In Beckmann’s rearrangement migration of group which is anti to-OH group takes place.

50. Beckmann’s rearrangement is a reaction of oximes in the presence of \( \text{H}_2\text{SO}_4 \) or \( \text{PCl}_5 \) to produce \( N \)-alkylamide derivatives.

51. Migratory attitude of alkyl group in Pinacol-pinacolone, beckmann’s and bayer villegar oxidation is

\[
\text{C}_6\text{H}_5 \rightarrow (\text{CH}_3)_2\text{C} \rightarrow (\text{CH}_3)_2\text{CH} \rightarrow \text{C}_2\text{H}_5 \rightarrow \text{CH}_3.
\]

52. Cyclohexanoneoxime on beckmann’s reaction gives caprolectum which on reaction with \( \text{H} \) to give polymer nylon-6.

53. 2-methyl propanal even contains -hydrogen atom but does not give aldol reaction.

54. Diphenyl glyoxal reacts with con. KOH to form salt of benzillic acid.

55. Propanone in the presence of dry HCl gas by enolic intermediate to form diacetone alcohol undergo heating form mesityl oxide. If this again reacts with propanone to form phoron.

56. Benzaldehyde reacts with alc. KCN to form Benzoin which on oxidation form benzil.

57. By wittig reaction carbonyl compounds are converted into E-Z form of alkene.

58. Benzaldehyde do not respond to benedict’s and fehling’s solution due to less reducing power of aromatic aldehyde.

59. HCOOH respond to oxidising agent due to presence of - CHO group.

60. \( \text{HI} > \text{H}_2\text{SO}_4 > \text{HNO}_3 > \text{RCOOH} > \text{H}_2\text{CO}_3 > \text{C}_6\text{H}_5\text{OH} > \text{H}_2\text{O} > \text{CH} \equiv \text{CH} > \text{NH}_3 > \text{CH}_3 \cdot \text{C} \equiv \text{CH} > \text{CH}_2 = \text{CH}_2 > \text{H}_2 \) this is decreasing acidic nature.

61. Acids with \( \equiv \)-hydrogen atom when reacts with halogen in the presence of P to form \( \equiv \)-haloacid (HVZ).

62. Carboxylic acid on reaction with \( \text{PCl}_5 \), \( \text{CH}_3\text{N}_2 \) and \( \text{H}_2\text{O} \) to form higher acid or next homologue.

63. For reactivity of acid derivatives use funda weaker the base better the leaving group.

64. Acid amide on reaction with \( \text{PCl}_5 \) to form alkane nitrile.

65. Anhydride on reaction with carbonyl compound in the presence of base (carbanian) forms \( \equiv \), \( \beta \)-unsaturated carboxylic acid (perkin reaction)
66. Amide on reaction with \( \text{Br}_2 \) and alkali to form primary amine of lower homologue. Intermediate species is nitrene which undergo intra rearrangement to form RNH₂.

67. Ester's with \( \equiv \)-hydrogen atom in the presence of strong base to form carbanion undergo nucleophilic substitution reaction forms \( \beta \)-keto ester for example ethyl acetate in the presence of pot. ter. Butoxide form aceto acetic ester (AAE). reaction is known as clesen’s ester condensation of four types

(a) Simple clesen’s ester condensation.
(b) CROSS clesen’s ester condensation.
(c) Intra CEC (Dieckmann’s condensation).
(d) mixed clesen ester condensation.

68. For a compound to be aromatic it must be cyclic, planar and obey \((4n + 2)\) electron rule.

69. Cyclooctatetraene is non aromatic compound while pyrrole, pyrene, furan, cyclopentadienylion all are aromatic.

70. In aromatic electrophilic substitution reaction there is no hydrogen isotopic effect except sulphonation and iodination.

71. \( m \)- directing groups like nitrobenzene and benzaldehyde cannot undergo fridal craft reaction.

72. Phenol is less acidic than general carboxylic acid, cannot react with NaHCO₃.

73. Anilene is more reactive than phenol towards electrophilic substitution reaction because less energy difference between nitrogen and carbon.

74. Benzene diazonium chloride reacts with phenol or aniline to form azo compounds.

75. \( \text{C}_6\text{H}_4\text{NH}_2 > \text{C}_6\text{H}_4\text{OH} > \text{C}_6\text{H}_4\text{OR} > \text{C}_6\text{H}_4\text{Br} > \text{C}_6\text{H}_4\text{NO}_2 \) (Reactivity towards electrophilic substitution reaction)

**General Series - Chemistry Fact Sheet - 3**

<table>
<thead>
<tr>
<th>General series</th>
<th>Order</th>
<th>Why?</th>
</tr>
</thead>
<tbody>
<tr>
<td>B.P. of ( \text{CH}_3\text{CH}_2\text{OH} ), ( \text{CH}_3\text{OCH}_3 ), ( \text{CH}_2\text{CH}_3 )</td>
<td>( I &gt; II &gt; III )</td>
<td>There is intermolecular H-bonding I. III has weak force of attraction and is most volatile. Intramolecular H-bonding in o-isomer makes it more volatile.</td>
</tr>
</tbody>
</table>
| B.P. of \( o \), \( m \), \( p \)-nitro phenol | \( o < m < p \) | }
3. Reactivity of ... with Tollen's reagent

\[
\begin{align*}
\text{I} & : \text{HCHO} \\
\text{II} & : \text{CH}_3\text{CHO} \\
\text{III} & : \text{CH}_2\text{COCH}_3 \\
\text{IV} & : \text{C}_6\text{H}_5\text{CHO}
\end{align*}
\]

I > II > IV > III

—CHO group is easily oxidised compared to keto group due to reducing hydrogen.

4. Reactivity of ... with Fehling's solution

I > II > IV > III

5. Extent of hydration of

\[
\begin{align*}
\text{I} & : \text{[Hydration diagram]} \\
\text{II} & : \text{[Hydration diagram]} \\
\text{III} & : \text{[Hydration diagram]} \\
\text{IV} & : \text{[Hydration diagram]}
\end{align*}
\]

I < II < III < IV

Aldehydes are more hydrated than ketones. Halide makes C of carbonyl group more electropositive.

6. Electrophilic nature of ....... for nucleophilic attack

\[
\begin{align*}
\text{I} & : \text{[Electrophilic attack diagram]} \\
\text{II} & : \text{[Electrophilic attack diagram]} \\
\text{III} & : \text{[Electrophilic attack diagram]}
\end{align*}
\]

I > II > III

CH₃ group decreases +ve charge on C hence nucleophilic attack.

7. Reactivity of isomeric 1°, 2°, 3° butyl halide towards elimination (E₁ or E₂)

3° < 2° < 1°

due to stability of intermediate carbocation

8. Dehydration of

\[
\begin{align*}
\text{I} & : \text{[Dehydration diagram]} \\
\text{II} & : \text{[Dehydration diagram]} \\
\text{III} & : \text{[Dehydration diagram]} \\
\text{IV} & : \text{[Dehydration diagram]}
\end{align*}
\]

IV < I < II < III

Alcohol leading to increase in conjugation due to dehydration is more easily dehydrated. IV is vinylic, hence least.

9. Stability of
Substituted alkenes are more stable. More the alkyl groups are attached to the doubly bonded carbon atom more is the stability.

10. Stability of
   
   ![Compounds](image)

   I < III < II

   I is more substituted than II (More hyperconjugation more stability)

11. Stability of
   
   ![Compounds](image)

   III > II > I

   IV is vinylic while in conjugative, II allylic.

12. Stability of
   
   ![Compounds](image)

   I < IV < II < III

   III is 3° allylic and II is 1° allylic

13. Dehydration of
   1°, 2°, 3° isomeric butyl alcohol

   3° < 2° < 1°

   More the stability of intermediate, greater the reactivity of chemical reaction.

14. Boiling points of
   n-butyl amine, n-butyl alcohol, n-pentane

   I > II > III

   I, II have H-bonding but electronegativity of O > N hence H-bonding in II > I.

15. Formation of

   ![Compounds](image)

   I > II > III > IV (easiest I)

   Greater the stability, easier the formation of particular species.

16. Reactivity of C–H bond (abstraction of H)
17. Leaving nature (tendency) of … in $S_N$ reaction.

<table>
<thead>
<tr>
<th>$H^+$, $R^+$, $MeO^-$, $OH^-$, $CN^-$, $CH_3COO^-$</th>
<th>$I$</th>
<th>$II$</th>
<th>$III$</th>
<th>$IV$</th>
<th>$V$</th>
<th>$VI$</th>
<th>$VII$</th>
<th>$VIII$</th>
</tr>
</thead>
</table>

If acid is strong, its conjugate base is weak and greater the leaving tendency.

18. Rate of esterification of the following acids with MeOH

Me$\text{CH}_2\text{COOH}$, Me$_2$CH$\text{COOH}$, Me$\text{COOH}$, Et$\text{CCOO}$ (I - Pr)$_2$CH$\text{COOH}$

<table>
<thead>
<tr>
<th>$I$</th>
<th>$II$</th>
<th>$III$</th>
<th>$IV$</th>
<th>$V$</th>
</tr>
</thead>
</table>

As the size of the substituents on the $\text{-C}$ increases, the tetrahedralily bonded interme. diate becomes more crowded and these slower the rate.

19. Relative reactivity of … with electrophile in $S_E$ reaction

<table>
<thead>
<tr>
<th>(I)</th>
<th>(II)</th>
<th>(III)</th>
<th>(IV)</th>
</tr>
</thead>
</table>

$\text{CH}_3$ is $\text{o-}$, $\text{p}$-directing and responsible for activation.

20. Relative reactivity of these compounds with electrophile in $S_E$ reaction

<table>
<thead>
<tr>
<th>(I)</th>
<th>(II)</th>
<th>(III)</th>
<th>(IV)</th>
</tr>
</thead>
</table>

$\text{CH}_3$ is $\text{o-}$, $\text{p}$-directing due to activation while $\text{-COOH}$ is $\text{m}$-directing and deactivating group.

21. Relative reactivity of … with electrophile in $S_E$ reaction.

<table>
<thead>
<tr>
<th>(I)</th>
<th>(II)</th>
<th>(III)</th>
<th>(IV)</th>
</tr>
</thead>
</table>

As the number of $\text{sp}^3$ hybridised C
Atoms separating the ring from the positively charged substituent increases, deactivating effect decreases due to less electronegativity.

—O⁻ is best able to donate electrons there by giving a very stable uncharged intermediate. In

conjugation diminished its ability to donate electrons to an arenium ion. Intermediates are benzylic cations. So CH₃O(electron repelling) gives greater stability through delocalisation while NO₂ (electron attracting) decreases stability.

22. Activating effects of the following o, p-directors.

II > I > III

23. Relative reactivity of ... towards S₈1 reaction

benzyl chloride, p - methoxy benzyl chloride

and p - nitro benzyl chloride

II > I > III

24. Relative reactivity of ... towards S₈1 and S₈2 reaction

PhCH₂Cl PhCH₂ClMe PhCClMe₂

(I) (II) (III)

(Ph stands for phenyl, C₆H₅)

S₈1 : III > II > I

S₈2 : II < II < I

S₈1 : 1° < 2° < 3° alkyl halide

S₈2 : 3° < 2° < 1° alkyl halide

25. Relative reactivity of ... with E⁺ (electrophile) in S₈ reaction.

II > I > III

—NO₂ deactivates benzene ring for S₈
26. Order of $S_n2$ reactivity of alkoxide nucleophiles

$I < IV < V < III < II$

$S_n2$ reactivity is susceptible to steric hindrance by the nucleophile as well as by the size of alkyl group.

Basic power - Chemistry Fact Sheet - 2

<table>
<thead>
<tr>
<th>Basic power</th>
<th>Order</th>
<th>Why?</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\text{N}$</td>
<td>$I &gt; III &gt; II$</td>
<td>lone pair on N is not used in resonance of $\pi$-electrons in I. In II lone pair of the ring is itself used in delocalisation while that of outside ring in III. $-\text{OCH}_3$ is strong electron donating group. This is due to ortho effect, all the aniline are less basic than $p$-substituted aniline due to steric hindrance. I (hyper conjugation and induction) II (induction) IV (ortho effect), ortho effect normally decreases basic nature.</td>
</tr>
<tr>
<td>$\text{NH}_2$</td>
<td>$I &gt; II &gt; III &gt; IV$</td>
<td></td>
</tr>
<tr>
<td>$\text{NH}_2$</td>
<td>$I &gt; II &gt; III &gt; IV$</td>
<td></td>
</tr>
</tbody>
</table>
4. In II there is $sp^3$ hybridised C, In I, $sp^2$. NO$_2$ is electron withdrawing.

5. lone pair on N is used in delocalisation of $\pi$-electrons in aromatic amines while cyclohexyl is electron repelling (III); in II, lone pair on N is used by two benzene ring. NO$_2$ is electron-withdrawing, thus nitro- anilines are less basic than aniline. IV is less basic than III because $-\text{NO}_2$ is closer and exerts a stronger inductive effect.

6. phenyl and $-\text{COCH}_3$ are electron withdrawing and $-\text{C}_6\text{H}_5 < \text{COCH}_3$

7. III > I > II Electron donating nature of $\text{C}_6\text{H}_5 > \text{CH}_3$ So more basic strength.
9. ![Chemical structures]

I < II < III  ortho effect in I.

10. ![Chemical structures]

I < II < III  ortho effect in (I)

Acidic Powers & Their Orders - Chemistry Fact Sheet

<table>
<thead>
<tr>
<th>Acidic power</th>
<th>Order</th>
<th>Why?</th>
</tr>
</thead>
<tbody>
<tr>
<td>1- 2- 3- chlorobutanoic acid</td>
<td>1 2 3</td>
<td>III &lt; II &lt; I Farther the (-I) group (Cl), lesser the acidic strength</td>
</tr>
<tr>
<td>1- 2- 3- methyl pentanoic acid</td>
<td>1 2 3</td>
<td>I &lt; II &lt; III Farther the (+I) group, greater the acidic power</td>
</tr>
<tr>
<td>2- 3- 1- phenol</td>
<td>2 3 1</td>
<td>II &lt; I &lt; III -CH₃ is electron donating and -NO₂ is electron attracting</td>
</tr>
<tr>
<td>3- 1- 2- phenol</td>
<td>3 1 2</td>
<td>II &lt; I &lt; III -CH₃ is electron repelling; decreases acidic strength of phenol</td>
</tr>
<tr>
<td>4- 1- 2- phenol</td>
<td>4 1 2</td>
<td>III &lt; I &lt; II -OCH₃ group contains +M effect and decreases acidic power</td>
</tr>
</tbody>
</table>

CBSE Standard 12 Chemistry Survival Guide - Reduction Methods by Prof. Subhashish Chattopadhyay
SKMClasses Bangalore Useful for IIT-JEE, I.Sc. PU-II, Boards, IGCSE IB AP-Chemistry and other exams
6. \[ \text{OH} \quad \text{OH} \quad \text{OH} \]
\[ \text{NO}_2 \quad \text{NO}_2 \quad \text{NO}_2 \]

I < II < III

- NO₂ is electron attracting; III is more resonance stabilised than I and also than II. In I, only inductive effect is operative. sp² hybridised carbon of I, II are more electronegative hence acid strength is increased.

Benzylic (C₆H₅CH₂) is more stabilised than allylic (CH₂=CHCH₂). Effect of one –COOH on the other decreases as its distance between them increases, (COOH)$_2$ is maximum acidic.

- NO₂ is electron attracting (–I effect)
- OH shows electron withdrawing nature at o- and m- and electron repelling at p-
- o- isomer due to intramolecular bonding in salicylate ion is stronger than m - isomer

7. \[ \text{CH₃COOH} \]
\[ \text{CH}_2=\text{CHCH}_2\text{COOH} \quad \text{CH}_3\text{CH}_2\text{COOH} \]

I > II > III

oxalic acid, succinic acid, malonic acid, adipic acid

8. adipic acid

I > II > III > IV

(all dibasic)

9. \[ \text{o- m- p- nitrobenzoic acid} \]

II < III < I

10. \[ \text{o- m- p- hydroxy benzoic acid} \]

III < II < I

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11. \( o^- m^- p^- \text{ methoxy benzoic acid} \) 
\( \text{III} < \text{II} < \text{I} \) —do— 

12. \( o^- m^- p^- \text{ amino benzoic acid} \) 
\( \text{I} < \text{III} < \text{II} \) —NH\(_2\) is electron donating.

**Topic wise grouping of information kind of Dictionary of Inorganic Chemistry**

Given two Equations

\( (1) \) \( \text{B}_2\text{O}_3 + 6\text{NaOH} \rightarrow (\text{X}) + 3\text{H}_2\text{O} \)

\( (2) \) \( \text{B}_2\text{O}_3 + 2\text{NaOH} \rightarrow (\text{Y}) + \text{H}_2\text{O} \)

What are (X) and (Y)?

Ans: X is Sodium Borate and Y is Sodium meta borate

\( \text{B}_2\text{O}_3 + 6\text{NaOH} \rightarrow 2\text{Na}_3\text{BO}_3 \) (Sodium Borate) + 3H\(_2\)O

\( \text{B}_2\text{O}_3 + 2\text{NaOH} \rightarrow 2\text{NaBO}_2 \) (Sodium metaborate) + H\(_2\)O

-
Silica is soluble in which of the following acids?

(1) HF  (2) HCl  (3) HBr  (4) HI

Solution: \( \text{SiO}_2 + 4\text{HF} \rightarrow \text{SiF}_4 + 2\text{H}_2\text{O} \) and again \( \text{SiF}_4 + 2\text{HF} \rightarrow \text{H}_2\text{SiF}_6 \) (Hydrofluosilicic acid)

\( \text{K}_3\text{Co(NO}_3\text{)}_6 \) is Fischer's Salt

The brown ring test for \( \text{NO}_3^- \) is due to formation of the complex \([\text{Fe}(\text{H}_2\text{O})_5\text{NO}]^{2+}\)  

Merck's perhydrol is 30.4% \( \text{H}_2\text{O}_2 \)

\( \text{H}_2\text{SO}_3 \), \( \text{H}_2\text{S}_2\text{O}_8 \) have peroxide linkages
Bromine reacting with NaOH in cold and hot give different mix of products. Specify

\[ \text{Br}_2 + 2\text{NaOH (cold)} \rightarrow \text{NaBr} + \text{NaOBr} + \text{H}_2\text{O} \]

\[ 3\text{Br}_2 + 6\text{NaOH (hot)} \rightarrow 5\text{NaBr} + \text{NaBrO}_3 + 3\text{H}_2\text{O} \]
Malachite decomposes to give A + CO₂ + H₂O and compound A on reduction with Carbon gives CO + B

Identify A and B

Solution: CuCO₃·Cu(OH)₂ → 2CuO (A) + CO₂ + H₂O

CuO + C → Cu (B) + CO

Some examples of Complex Anions

K₂PtCl₆ <===> 2K⁺ + [PtCl₆]²⁻

Na₃AlF₆ <===> 3Na⁺ + AlF₆⁻³

K₂SiF₆ <===> 2K⁺ + SiF₆²⁻
and $\text{ICl}_2^-$

Sp$^3$d hybridization for $\text{I}_3^-$ and $\text{ICl}_2^-$

The ionization potential of Pb is higher than Sn due to poor shielding by 14f electrons present in Pb

Selenous acid $\text{H}_2\text{SeO}_3$ (Oxidation Number of Se is +4)

Telluric acid $\text{H}_6\text{TeO}_6$ (Oxidation Number of Te is +6)

Electronegativity Values (in Pauling Scale)

Microcosmic Salt is $\text{Na(NH}_4\text{)}\text{HPO}_4$ Sodium ammonium hydrogen phosphate
Which of the following electrolyte will be most effective in coagulation of gold sol?

(1) NaNO₃  
(2) K₄Fe(CN)₆  
(3) Na₃PO₄  
(4) MgCl₂

Gold sol is a negatively charged coagulation which is carried out by positively charged ion furnished by electrolyte. Coagulating power depends on the valency of cation of electrolyte. (Schulze Hardy Law) Mg²⁺ ion has highest valency so MgCl₂ is most effective.

Organometallic compounds are Metal atoms directly linked with Carbon. So Ti(OC₃H₇)₄ is not an organometallic compound.
IUPAC name of Diamminetetraaquacobalt III chloride

As per IUPAC nomenclature, the name of the complex \([\text{Co(H}_2\text{O})_6\text{(NH}_3)_2\text{]} \text{Cl}_3\) is

(a) Tetraaquadiamminecobalt(III) chloride  
(b) Tetraaquadiamminecobalt(III) chloride  
(c) Diamminetetraaquacobalt(III) chloride  
(d) Diamminetetraaquacobalt(III) chloride

Solution:
While naming a complex, the ligands are quoted in alphabetical order, regardless of their charges (followed by the metal). The oxidation state of the central metal is shown by a Roman numeral in brackets immediately following the metal name without any intervening blank. \(\text{NH}_3\) is named as ammine and not as amine. Hence, the IUPAC name of the given compound is Diamminetetraaquacobalt(III) chloride.
Therefore, the choice (d) is correct.

Color of light absorbed by aqueous solution of \(\text{CuSO}_4\)

The colour of light absorbed by an aqueous solution of \(\text{CuSO}_4\) is

(a) orange-red  
(b) blue-green  
(c) yellow  
(d) violet

Solution:
An aqueous solution of \(\text{CuSO}_4\) is blue. The colour of light absorbed by this solution is that of complimentary colour which is orange-red.
Therefore, the choice (a) is correct.
Temperature dependent Magnetic behaviour

NiCl₂{(P(C₂H₅)₂)₂(C₅H₅)₂}₂ exhibits temperature dependent magnetic behaviour (paramagnetic/diamagnetic). The coordination geometries of Ni²⁺ in the paramagnetic and diamagnetic states are respectively
(a) tetrahedral and tetrahedral  
(b) square planar and square planar  
(c) tetrahedral and square planar  
(d) square planar and tetrahedral.

Solution:
In the paramagnetic state, the complex will have unpaired 3d electrons in Ni²⁺ ion, whereas no such electrons (i.e. all the 3d electrons will be paired) are present in the diamagnetic state.

The electronic configuration of 2₃Ni²⁺ is

\[
\begin{array}{cccc}
\uparrow & \uparrow & \uparrow & \uparrow \\
4s & & & 4p
\end{array}
\]

If the two unpaired electrons remain present in the ion, it will undergo sp³ hybridization to accommodate ligands and the geometry of the complex ion will be tetrahedral.

If the two unpaired electrons are coupled, the ion will be diamagnetic and it can undergo dsp³ hybridization to accommodate ligands leading to the square planar geometry to the complex ion.

Therefore, the choice (c) is correct.
Reaction of white phosphorus with aqueous NaOH

The reaction of white phosphorus with aqueous NaOH gives phosphine along with another phosphorus containing compound. The reaction type, the oxidation states of phosphorus in phosphine and the other product, respectively, are:

(a) redox reaction, −3 and −5
(b) redox reaction, 3 and +5
(c) disproportionation reaction, −3 and +5
(d) disproportionation reaction, −3 and +3

Solution:

The reaction is:

\[ P_4 + 3\text{NaOH} + 3\text{H}_2\text{O} \rightarrow \text{PH}_3 + 3\text{NaH}_2\text{PO}_2 \]

The salt NaH_2PO_2 undergoes the following changes on heating:

\[ 4\text{NaH}_2\text{PO}_2 \rightarrow \text{Na}_4\text{P}_2\text{O}_7 + 2\text{PH}_3 + \text{H}_2\text{O} \]

The reaction is disproportionation reaction and the oxidation states of phosphorus are −3 (in phosphine) and +5 in the second product.

Therefore, the choice (c) is correct.

Generally the stabilities of complexes decreases with increasing atomic number for the electropositive metals e.g. group IIA or hard Lewis acids, and increase with increasing atomic number for the noble metals (soft acids), following the general trend of ionization energy.

(a) For electropositive metals (hard acids) the order of stabilities of the Halide complexes F > Cl > Br > I but for highly polarizing soft acid metal ions such as Hg^{2+}, we see the reverse order.

(b) The most electropositive metals (hardest acids) show a greater tendency of forming complexes, with hard ligands such as F or Oxygen containing ligands.
Metals are classified according to their acceptor properties.

Class A - Hard Acids. Show affinities to ligands whose basicity is proportional to protons.

Class B - Soft acids form stable olefin complexes.

Class C - Borderline metals
cyanide extraction process of silver from argentite ore

In the cyanide extraction process of silver from argentite ore, the oxidizing and reducing agents used are
(a) O₂ and CO₂, respectively
(b) O₂ and Zn dust, respectively
(c) HNO₃ and Zn, respectively
(d) HNO₃ and CO, respectively

Solution:
The argentite ore contains Ag₂S. After crushing and concentration by froth flotation process, the ore is leached with 0.4 – 7% solution of sodium cyanide kept agitated with a current of air.
Silver passes into the solution as argentocyanide. \[ \text{Ag}_2\text{S} + 4\text{NaCN} \rightleftharpoons 2\text{Na}[\text{Ag(CN)}_2] + \text{Na}_2\text{S} \]
The air blown removes Na$_2$S as Na$_2$S$_2$O$_3$ and Na$_2$SO$_4$ causing the above reaction to proceed to completion. Silver is recovered by adding zinc into argentocyanide. \[ 2\text{Ag(CN)}_2^- + \text{Zn} \rightarrow [\text{Zn(CN)}_4]^{2^-} + 2\text{Ag} \]
Thus, oxidizing agent is O$_2$ (from air) and the reducing agent is Zn.
Therefore, the choice (b) is correct.

Magnitude of electron affinity (kJ/mol), s-, p-, and d-block elements

- **s block**
- **p block**
- **d block**
- **f block**
<table>
<thead>
<tr>
<th>Common Name</th>
<th>Chemical Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>acetone</td>
<td>dimethyl ketone; 2-propanone (usually known as acetone)</td>
</tr>
<tr>
<td>acid potassium sulfate</td>
<td>potassium bisulfate</td>
</tr>
<tr>
<td>acid of sugar</td>
<td>oxalic acid</td>
</tr>
<tr>
<td>ackey</td>
<td>nitric acid</td>
</tr>
<tr>
<td>alcali volatil</td>
<td>ammonium hydroxide</td>
</tr>
<tr>
<td>alcohol, grain</td>
<td>ethyl alcohol</td>
</tr>
<tr>
<td>alcohol sulfuris</td>
<td>carbon disulfide</td>
</tr>
<tr>
<td>alcohol, wood</td>
<td>methyl alcohol</td>
</tr>
<tr>
<td>alum</td>
<td>aluminum potassium sulfate</td>
</tr>
<tr>
<td>alumina</td>
<td>aluminum oxide</td>
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<tr>
<td>antichlor</td>
<td>sodium thiosulfate</td>
</tr>
<tr>
<td>antimony black</td>
<td>antimony trisulfide</td>
</tr>
<tr>
<td>antimony bloom</td>
<td>antimony trioxide</td>
</tr>
<tr>
<td>antimony glance</td>
<td>antimony trisulfide</td>
</tr>
<tr>
<td>antimony red (vermillion)</td>
<td>antimony oxysulfide</td>
</tr>
<tr>
<td>aqua ammonia</td>
<td>aqueous solution of ammonium hydroxide</td>
</tr>
<tr>
<td>aqua fortis</td>
<td>nitric acid</td>
</tr>
<tr>
<td>aqua regia</td>
<td>nitrohydrochloric acid</td>
</tr>
<tr>
<td>aromatic spirit of ammonia</td>
<td>ammonia in alcohol</td>
</tr>
<tr>
<td>arsenic glass</td>
<td>arsenic trioxide</td>
</tr>
<tr>
<td>azurite</td>
<td>mineral form of basic copper carbonate</td>
</tr>
<tr>
<td>asbestos</td>
<td>magnesium silicate</td>
</tr>
<tr>
<td>aspirin</td>
<td>acetylsalicylic acid</td>
</tr>
<tr>
<td>baking soda</td>
<td>sodium bicarbonate</td>
</tr>
<tr>
<td>banana oil (artificial)</td>
<td>isoamyl acetate</td>
</tr>
<tr>
<td>barium white</td>
<td>barium sulfate</td>
</tr>
<tr>
<td>benzoil</td>
<td>benzene</td>
</tr>
<tr>
<td>bicarbonate of soda</td>
<td>sodium hydrogen carbonate or sodium bicarbonate</td>
</tr>
<tr>
<td>bichloride of mercury</td>
<td>mercuric chloride</td>
</tr>
<tr>
<td>bichrome</td>
<td>potassium dichromate</td>
</tr>
<tr>
<td>bitter salt</td>
<td>magnesium sulfate</td>
</tr>
<tr>
<td>black ash</td>
<td>crude form of sodium carbonate</td>
</tr>
</tbody>
</table>
black copper oxide       cupric oxide
black lead              graphite (carbon)
blanc-fixe              barium sulfate
bleaching powder        chlorinated lime; calcium hypochlorite
blue copperas           copper sulfate (crystals)
blue lead               lead sulfate
blue salts              nickel sulfate
blue stone              copper sulfate (crystals)
blue vitriol            copper sulfate
bluestone               copper sulfate
bone ash                crude calcium phosphate
bone black              crude animal charcoal
boracic acid            boric acid
borax                   sodium borate; sodium tetraborate
bremen blue             basic copper carbonate
brimstone               sulfur
burnt alum              anhydrous potassium aluminum sulfate
burnt lime              calcium oxide
burnt ochre             ferric oxide
burnt ore               ferric oxide
brine                   aqueous sodium chloride solution
butter of antimony      antimony trichloride
butter of tin           anhydrous stannic chloride
butter of zinc          zinc chloride
calomel                 mercury chloride; mercurous chloride
carbolic acid           phenol
carbonic acid gas       carbon dioxide
caustic lime            calcium hydroxide
caustic potash          potassium hydroxide
caustic soda            sodium hydroxide
chalk                   calcium carbonate
Chile saltpeter         sodium nitrate
Chile nitre             sodium nitrate
<table>
<thead>
<tr>
<th>Term</th>
<th>Carbonate Compounds</th>
</tr>
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<tbody>
<tr>
<td>Chinese red</td>
<td>basic lead chromate</td>
</tr>
<tr>
<td>Chinese white</td>
<td>zinc oxide</td>
</tr>
<tr>
<td>chloride of soda</td>
<td>sodium hypochlorite</td>
</tr>
<tr>
<td>chloride of lime</td>
<td>calcium hypochlorite</td>
</tr>
<tr>
<td>chrome alum</td>
<td>chromic potassium sulfate</td>
</tr>
<tr>
<td>chrome green</td>
<td>chromium oxide</td>
</tr>
<tr>
<td>chrome yellow</td>
<td>lead (VI) chromate</td>
</tr>
<tr>
<td>chromic acid</td>
<td>chromium trioxide</td>
</tr>
<tr>
<td>copperas</td>
<td>ferrous sulfate</td>
</tr>
<tr>
<td>corrosive sublimate</td>
<td>mercury (II) chloride</td>
</tr>
<tr>
<td>corundum (ruby, sapphire)</td>
<td>chiefly aluminum oxide</td>
</tr>
<tr>
<td>cream of tartar</td>
<td>potassium bitartrate</td>
</tr>
<tr>
<td>crocus powder</td>
<td>ferric oxide</td>
</tr>
<tr>
<td>crystal carbonate</td>
<td>sodium carbonate</td>
</tr>
<tr>
<td>dechlor</td>
<td>sodium thiophosphate</td>
</tr>
<tr>
<td>diamond</td>
<td>carbon crystal</td>
</tr>
<tr>
<td>emery powder</td>
<td>impure aluminum oxide</td>
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<tr>
<td>epsom salts</td>
<td>magnesium sulfate</td>
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<tr>
<td>ethanol</td>
<td>ethyl alcohol</td>
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<tr>
<td>farina</td>
<td>starch</td>
</tr>
<tr>
<td>ferro prussiate</td>
<td>potassium ferricyanide</td>
</tr>
<tr>
<td>ferrum</td>
<td>iron</td>
</tr>
<tr>
<td>flores martis</td>
<td>anhydride iron (III) chloride</td>
</tr>
<tr>
<td>fluor spar</td>
<td>natural calcium fluoride</td>
</tr>
<tr>
<td>fixed white</td>
<td>barium sulfate</td>
</tr>
<tr>
<td>flowers of sulfur</td>
<td>sulfur</td>
</tr>
<tr>
<td>'flowers of' any metal</td>
<td>oxide of the metal</td>
</tr>
<tr>
<td>formalin</td>
<td>aqueous formaldehyde solution</td>
</tr>
<tr>
<td>French chalk</td>
<td>natural magnesium silicate</td>
</tr>
<tr>
<td>French vergidris</td>
<td>basic copper acetate</td>
</tr>
<tr>
<td>galena</td>
<td>natural lead sulfide</td>
</tr>
<tr>
<td>Glauber's salt</td>
<td>sodium sulfate</td>
</tr>
<tr>
<td>green verditer</td>
<td>basic copper carbonate</td>
</tr>
<tr>
<td>Term</td>
<td>Definition</td>
</tr>
<tr>
<td>----------------------</td>
<td>------------------------------------------------</td>
</tr>
<tr>
<td>green vitriol</td>
<td>ferrous sulfate crystals</td>
</tr>
<tr>
<td>gypsum</td>
<td>natural calcium sulfate</td>
</tr>
<tr>
<td>hard oil</td>
<td>boiled linseed oil</td>
</tr>
<tr>
<td>heavy spar</td>
<td>barium sulfate</td>
</tr>
<tr>
<td>hydrocyanic acid</td>
<td>hydrogen cyanide</td>
</tr>
<tr>
<td>hypo (photography)</td>
<td>sodium thiosulfate solution</td>
</tr>
<tr>
<td>Indian red</td>
<td>ferric oxide</td>
</tr>
<tr>
<td>Isinglass</td>
<td>agar-agar gelatin</td>
</tr>
<tr>
<td>jeweler's rouge</td>
<td>ferric oxide</td>
</tr>
<tr>
<td>killed spirits</td>
<td>zinc chloride</td>
</tr>
<tr>
<td>lampblack</td>
<td>crude form of carbon; charcoal</td>
</tr>
<tr>
<td>laughing gas</td>
<td>nitrous oxide</td>
</tr>
<tr>
<td>lead peroxide</td>
<td>lead dioxide</td>
</tr>
<tr>
<td>lead protoxide</td>
<td>lead oxide</td>
</tr>
<tr>
<td>lime</td>
<td>calcium oxide</td>
</tr>
<tr>
<td>lime, slaked</td>
<td>calcium hydroxide</td>
</tr>
<tr>
<td>limewater</td>
<td>aqueous solution of calcium hydroxide</td>
</tr>
<tr>
<td>liquor ammonia</td>
<td>ammonium hydroxide solution</td>
</tr>
<tr>
<td>litharge</td>
<td>lead monoxide</td>
</tr>
<tr>
<td>lunar caustic</td>
<td>silver nitrate</td>
</tr>
<tr>
<td>liver of sulfur</td>
<td>sulfurated potash</td>
</tr>
<tr>
<td>lye or soda lye</td>
<td>sodium hydroxide</td>
</tr>
<tr>
<td>magnesia</td>
<td>magnesium oxide</td>
</tr>
<tr>
<td>manganese black</td>
<td>manganese dioxide</td>
</tr>
<tr>
<td>marble</td>
<td>mainly calcium carbonate</td>
</tr>
<tr>
<td>mercury oxide, black</td>
<td>mercurous oxide</td>
</tr>
<tr>
<td>methanol</td>
<td>methyl alcohol</td>
</tr>
<tr>
<td>methylated spirits</td>
<td>methyl alcohol</td>
</tr>
<tr>
<td>milk of lime</td>
<td>calcium hydroxide</td>
</tr>
<tr>
<td>milk of magnesium</td>
<td>magnesium hydroxide</td>
</tr>
<tr>
<td>milk of sulfur</td>
<td>precipitated sulfur</td>
</tr>
<tr>
<td>&quot;muriate&quot; of a metal</td>
<td>chloride of the metal</td>
</tr>
<tr>
<td>muriatic acid</td>
<td>hydrochloric acid</td>
</tr>
<tr>
<td>Term</td>
<td>Substance</td>
</tr>
<tr>
<td>-----------------------------</td>
<td>----------------------------------------</td>
</tr>
<tr>
<td>natron</td>
<td>sodium carbonate</td>
</tr>
<tr>
<td>nitre</td>
<td>potassium nitrate</td>
</tr>
<tr>
<td>nordhausen acid</td>
<td>fuming sulfuric acid</td>
</tr>
<tr>
<td>oil of mars</td>
<td>deliquescent anhydrous iron (III) chloride</td>
</tr>
<tr>
<td>oil of vitriol</td>
<td>sulfuric acid</td>
</tr>
<tr>
<td>oil of wintergreen (artificial)</td>
<td>methyl salicylate</td>
</tr>
<tr>
<td>orthophosphoric acid</td>
<td>phosphoric acid</td>
</tr>
<tr>
<td>Paris blue</td>
<td>ferric ferrocyanide</td>
</tr>
<tr>
<td>Paris green</td>
<td>copper acetoarsenite</td>
</tr>
<tr>
<td>Paris white</td>
<td>powdered calcium carbonate</td>
</tr>
<tr>
<td>pear oil (artificial)</td>
<td>isoamyl acetate</td>
</tr>
<tr>
<td>pearl ash</td>
<td>potassium carbonate</td>
</tr>
<tr>
<td>permanent white</td>
<td>barium sulfate</td>
</tr>
<tr>
<td>plaster of Paris</td>
<td>calcium sulfate</td>
</tr>
<tr>
<td>plumbago</td>
<td>graphite</td>
</tr>
<tr>
<td>potash</td>
<td>potassium carbonate</td>
</tr>
<tr>
<td>potassa</td>
<td>potassium hydroxide</td>
</tr>
<tr>
<td>precipitated chalk</td>
<td>calcium carbonate</td>
</tr>
<tr>
<td>Prussic acid</td>
<td>hydrogen cyanide</td>
</tr>
<tr>
<td>pyro</td>
<td>tetrasodium pyrophosphate</td>
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<tr>
<td>quicklime</td>
<td>calcium oxide</td>
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<tr>
<td>quicksilver</td>
<td>mercury</td>
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<tr>
<td>red lead</td>
<td>lead tetraoxide</td>
</tr>
<tr>
<td>red liquor</td>
<td>aluminum acetate solution</td>
</tr>
<tr>
<td>red prussiate of potash</td>
<td>potassium ferrocyanide</td>
</tr>
<tr>
<td>red prussiate of soda</td>
<td>sodium ferrocyanide</td>
</tr>
<tr>
<td>Rochelle salt</td>
<td>potassium sodium tartrate</td>
</tr>
<tr>
<td>rock salt</td>
<td>sodium chloride</td>
</tr>
<tr>
<td>rouge, jeweler's</td>
<td>ferric oxide</td>
</tr>
<tr>
<td>rubbing alcohol</td>
<td>isopropyl alcohol</td>
</tr>
<tr>
<td>sal ammoniac</td>
<td>ammonium chloride</td>
</tr>
<tr>
<td>sal soda</td>
<td>sodium carbonate</td>
</tr>
<tr>
<td>salt, table</td>
<td>sodium chloride</td>
</tr>
</tbody>
</table>
salt of lemon  
potassium binoxalate
salt of tartar  
potassium carbonate
saltpeter  
potassium nitrate
silica  
silicon dioxide
slaked lime  
calcium hydroxide
soda ash  
sodium carbonate
soda nitre  
sodium nitrate
soda lye  
sodium hydroxide
soluble glass  
sodium silicate
sour water  
dilute sulfuric acid
spirit of hartshorn  
ammonium hydroxide solution
spirit of salt  
hydrochloric acid
spirit of wine  
ethyl alcohol
spirits of nitrous ether  
ethyl nitrate
sugar, table  
sucrose
sugar of lead  
lead acetate
sulfuric ether  
ethyl ether
talc or talcum  
magnesium silicate
tin crystals  
stannous chloride
trona  
natural sodium carbonate
unslaked lime  
calcium oxide
Venetian red  
ferric oxide
verdigris  
basic copper acetate
Vienna lime  
calcium carbonate
vinegar  
impure dilute acetic acid
vitamin C  
ascorbic acid
vitriol  
sulfuric acid
washing soda  
sodium carbonate
water glass  
sodium silicate
white caustic  
sodium hydroxide
white lead  
basic lead carbonate
white vitriol  
zinc sulfate crystals
yellow prussiate of potash  
potassium ferrocyanide
yellow prussiate of soda  sodium ferrocyanide
zinc vitriol  zinc sulfate
zinc white  zinc oxide

Westron - A refrigerant. \( \text{C}_2\text{H}_2\text{Cl}_4 \)

Colours of Compounds

**Cr\(_2\text{(SO}_4\text{)}_3\)** - green

**PbS** - Black

**[Fe(H}_2\text{O}_5\text{NO}]\text{SO}_4\** - brown

**(CH}_3\text{COO}_3\text{Fe** - blood red
NH₄Cl - white fumes

AgCl - curdy white precipitate

AgCl + NH₄OH → Ag(NH₃)₂Cl + H₂O

CrO₃ + HCl → CrO₂Cl₂ (deep red fumes) + H₂O
NaOH + CrO₂Cl₂ –> Na₂CrO₄ (yellow) + NaCl + H₂O

Na₂CrO₄ (yellow)

Na₂CrO₄ + Pb(CH₃COO)₂ –> PbCrO₄ (yellow) + CH₃COONa

NaBr + AgNO₃ –> AgBr (pale yellow) + NaNO₃
Ammonia test for silver halides. Test tubes and the results of using concentrated ammonia to test for the presence of three silver halides. Each one of the silver halides is next to a fuller test tube that shows the result of adding concentrated ammonia. Halides are compounds containing halogens such as here, from left to right silver chloride, silver bromide and silver iodide. Adding dilute ammonia dissolves the chloride, while concentrated ammonia is needed to dissolve the bromide, but it fails to dissolve the iodide. The silver halides are themselves the results of standard tests using silver nitrate to test for the halide ions.

BrCl - pale yellow
NaI + AgNO₃ → AgI (yellow ppt) + NaNO₃

Cu + HNO₃ → Cu(NO₃)₂ + NO₂ + H₂O

Cu(NO₃)₂

NO₂

H₃BO₃ + C₂H₅OH → (C₂H₅)₃BO₃ + H₂O (greenish flame)

H₃PO₄ + 12(NH₄)₂MoO₄ + HNO₃ → (NH₄)₃.PO₄.12MoO₃ (canary yellow) + 21 NH₄NO₃ + 12 H₂O
In the presence of Arsenic, we get yellow precipitate of (NH₄)₃AsO₄.12MoO₃ (ammonium arsenomolydate)

Mo₃O₈.xH₂O - molybdenum blue

SiF₄ + H₂O → H₄SiO₄ (silicic acid - white) + H₂SiO₄
Na₂S + Na₂[Fe(CN)₅NO] → Na₄[Fe(CN)₅NOS) - violet colour

Na₂S + CdCO₃ → CdS (yellow) + Na₂CO₃

Na₃[Co(NO₂)₆] + KCl → K₃[Co(NO₂)₆] (potassium cobalt nitrate - yellow ppt) + NaCl

AgCl, PbCl₂, Hg₂Cl₂ - white
PbCl₂ is white

Hg₂Cl₂ is white

H₂S, PbS, Bi₂S₃, CuS - black

H₂S is Black
PbS is Black

Bi₂S₃ is Black

CuS - black

CdS, As₂S₃, SnS₂ - Yellow

CdS is Yellow

As₂S₃ is Yellow
SnS\(_2\) is Yellow

Sb\(_2\)S\(_3\) is orange
SnS is Brown

Cr(OH)₃ is green

Chromium (III) Oxide is Green

CoS, NiS - black

CoS is black
NiS is Black Mineral Millerite

Cobalt Oxide is Black

Cobalt Sulphate is deep red brown
Cobalt Nitrate is deep red brown

Cobalt Chloride is deep Brown red

Cobalt Acetate is deep Brown

Azulene - Deep Bue

Iodoform - CHI₃ Yellow

Iron Phenol complex - Violet - [ Fe ( OC₆H₅)₆ ]³⁻

6 C₆H₅OH + FeCl₃ - -> [ Fe ( OC₆H₅)₆ ]³⁻ + 3 H⁺ + Cl⁻

Ammonium Phosphomolybdate - Yellow - (NH₄)₃PO₄.12MoO₃ ( Yellow )

Prusian Blue - Fe₄ [Fe(CN)₆]₃.xH₂O

[Fe(CN)₃NOS ]⁴⁻ - Violet

[Fe(SCN)]²⁺ - Blood Red

[Co(NH₃)₅ Br]⁺² SO₄⁻² - Violet - Pentaaminebromocobalt(III)sulphate
[Co(NH$_3$)$_5$SO$_4$]$^-$ $\rightarrow$ Red

**Test for Halogen:**

Halogens present in an organic compound forms sodium halide on fusion with sodium metal. Sodium halide extracted with water can be easily identified by adding silver nitrate solution after acidifying with dil. HNO$_3$.

If chlorine is present, a white curdy precipitate soluble in ammonium hydroxide solution is formed.

$$\text{Na} + \text{Cl} \rightarrow \text{NaCl}$$

$$\text{NaCl} + \text{AgNO}_3 \rightarrow \text{AgCl} + \text{NaNO}_3$$

If bromine is present, an yellowish white precipitate sparingly soluble in ammonium hydroxide solution is formed.

$$\text{Na} + \text{Br} \rightarrow \text{NaBr}$$

$$\text{NaBr} + \text{AgNO}_3 \rightarrow \text{AgBr} + \text{NaNO}_3$$

If iodine is present, an yellow precipitate insoluble in ammonium hydroxide solution is formed.

$$\text{Na} + \text{I} \rightarrow \text{NaI}$$

$$\text{NaI} + \text{AgNO}_3 \rightarrow \text{AgI} + \text{NaNO}_3$$

**Test for Nitrogen:**

The carbon and nitrogen present in the organic compound on fusion with sodium metal gives sodium cyanide (NaCN) soluble in water. This is converted in to sodium ferrocyanide by the addition of sufficient quantity of ferrous sulphate. Ferric ions generated during the process react with ferrocyanide to form prussian blue precipitate of ferric ferrocyanide.

$$\text{Na} + \text{C} + \text{N} \rightarrow \text{NaCN}$$

$$6\text{NaCN} + \text{FeSO}_4 \rightarrow \text{Na}_4[\text{Fe(CN)}_6] + \text{Na}_2\text{SO}_4$$

Sodium ferrocyanide

$$\text{Na}_4[\text{Fe(CN)}_6] + \text{Fe}^{3+} \rightarrow \text{Fe}_4[\text{Fe(CN)}_6]_3$$

Ferric ferrocyanide
FeCl₃ + K₄[Fe(CN)₆] -> Fe₄[Fe(CN)₆]₃ (prussian blue) + KCl

Test for Sulphur:

If sulphur is present in the organic compound, sodium fusion will convert it into sodium sulphide.
Sulphide ions are readily identified using sodium nitroprusside.

Na + S → Na₂S

Na₂S + Na₂[Fe(CN)₅NO] → Na₄[Fe(CN)₅NOS]

Sodium nitroprusside violet colour

Test for both Nitrogen and Sulphur:

If both nitrogen and sulphur are present in an organic compound, sodium fusion will convert it into sodium thiocyanate which then react with Fe³⁺ to form blood colour complex [Fe(SCN)]²⁺

Na + C + N + S → NaSCN

Fe³⁺ + 2Na → [Fe(SCN)]²⁺

Note: If the Lassaigne's extract containing excess of sodium metal, sodium cyanide and sulphides are formed instead of sodium thiocyanate.

NaSCN + 2Na → NaCN + Na₂S

Here in this type of cases, both sulphur and nitrogen are to be identified in separate tests.
BaCO₃, SrCO₃, CaCO₃, Mg(NH₄)PO₄ - white

BaCO₃ is white

SrCO₃ is white

CaCO₃ powder is white

CaCO₃ Calcium Carbonate Powder
Mg(NH₄)PO₄ is white

Pentaamminechlorocobalt(III)Bromide

\[
[\text{Co(NH}_3\text{)}_5\text{Cl}]^2+ \quad \text{Pentaamminechlorocobalt(III)chloride}
\]

\[
[\text{Co(NH}_3\text{)}_5\text{Br}]^2+ \quad \text{Pentaamminesulphatocobalt(III)Bromide}
\]

Dark Yellow

Pale Yellow

CBSE Standard 12 Chemistry Survival Guide - Reduction Methods by Prof. Subhashish Chattopadhyay
SKMClasses Bangalore Useful for IIT-JEE, I.Sc. PU-II, Boards, IGCSE IB AP-Chemistry and other exams
Eta bonds - Also known as Hapticity - Hapticity is the coordination of a ligand to a metal center via an uninterrupted and contiguous series of atoms.

The hapticity of a ligand is described with the Greek letter \( \eta \) (‘eta’). For example, \( \eta^2 \) describes a ligand that coordinates through 2 contiguous atoms. In general the \( \eta \)-notation only applies when multiple atoms are coordinated (otherwise the \( \kappa \)-notation is used). In addition, if the ligand coordinates through multiple atoms that are not contiguous then this is considered denticity (not hapticity), and the \( \kappa \)-notation is used once again. Lastly, bridging ligands are described with the \( \mu \) (‘mu’) notation.

**Ferrocene - bis(\( \eta^5 \)-cyclopentadienyl)iron**

**Uranocene - bis(\( \eta^8 \)-1,3,5,7-cyclooctatetraene)uranium**
W(CO)₃(PPr₃)₂(η2-H₂) - the first compound to be synthesized with a dihydrogen ligand (also known as Dihydrogen Complexes)
IrCl(CO)[P(C₆H₅)₃]₂(η2-O₂) - the dioxygen derivative which forms reversibly upon oxygenation of Vaska's complex.

Chromium (III) chloride is purple

HgCl₂ + NH₄OH → (Hg + Hg(NH₂)Cl) + NH₄Cl + H₂O
black ppt

BiCl₃ + H₂O → BiOCl (white) + HCl

Bi(OH)₃ Bismuth Hydroxide is white
Oxidation of Phenol

Test of Phenol

With Neutral FeCl₃, Phenol on reaction with neutral ferric chloride gives violet colour of ferric phenoxide

\[
\text{C}_6\text{H}_5\text{OH} \xrightarrow{\text{FeCl}_3} (\text{C}_6\text{H}_5\text{O})_\text{Fe} \quad \text{Violet colour}
\]

\[
\text{Cu(NO}_3\text{)}_2 + \text{K}_4\text{[Fe(CN)}_6\text{]} \rightarrow \text{Cu}_2\text{[Fe(CN)}_6\text{]} \text{ (Chocolate brown)} + \text{KNO}_3
\]

\[
\text{Cd(NH}_3\text{)}_4\text{(NO}_3\text{)}_2 + \text{H}_2\text{S} \rightarrow \text{CdS} \text{ (yellow)} + \text{NH}_4\text{NO}_3 + \text{NH}_3
\]
HgCl₂ + SnCl₂ → Hg₂Cl₂ (white) + SnCl₄

Liebermann’s Nitroso Reaction

SbCl₃ + H₂O → SbOCl (white) + HCl

SbOCl Antimony oxychloride
Antimony Trioxide is white

Antimony Pentoxide is gray

Antimony Trichloride is white
Potassium antimonate white

\[ \text{FeCl}_3 + \text{KSCN} \rightarrow \text{Fe(CNS)}_3 \text{ (blood red)} + \text{KCN} \]

Can Test

Treat a few drops of ceric ammonium nitrate with 3-4 ml of hot aqueous solution of the organic compound. A green or brown precipitate is formed.

\[
\left(\text{NH}_4\right)_2[\text{Ce(NO}_3)_3] + 2\text{C}_6\text{H}_5\text{OH} \rightarrow [\text{Ce(NO}_3)_4 \left(\text{C}_6\text{H}_5\text{OH}\right)_2] + 2\text{NH}_4\text{NO}_3 \\
\text{CAN} \quad \text{Phenol} \quad \text{green or brown ppt.}
\]

Phenol gives blue colour with ammonia and sodium hypo chloride.

\[ \text{ZnCl}_2 + 2\text{NaOH} \rightarrow \text{Zn(OH)}_2 \text{ (white ppt)} + 2\text{NaCl} \]
Zn(OH)₂ + NaOH → Na₂ZnO₂ (soluble) + H₂O

Na₂ZnO₂ + H₂S → ZnS (white) + NaOH

2KI + H₂O + O₃ → 2KOH + O₂ + I₂

Potassium iodide, Ozone, Potassium hydroxide, Iodine (Violet vapors)

Mn(NO₃)₂ + Pb₃O₄ + HNO₃ → HMnO₄ (pink) + Pb(NO₃)₂ + H₂O
Co(NO$_2$)$_3$ + KNO$_2$ -> K$_3$[Co(NO$_2$)$_6$] (yellow)

Na$_4$Co(CO$_3$)$_2$ + H$_2$O + [O] -> Na$_3$Co(CO$_3$)$_2$ (green coloration) + NaOH
\[ \text{NiCO}_3 + [O] \rightarrow \text{Ni}_2\text{O}_3 \text{ (black)} + \text{CO}_2 \]

\[ \text{MgCl}_2 + \text{Na}_2\text{HPO}_4 + \text{NH}_4\text{OH} \rightarrow \text{Mg(NH}_4\text{)PO}_4 \text{ (white)} + \text{NaCl} + \text{H}_2\text{O} \]
K$_2$HgI$_4$ + NH$_4$Cl + KOH $\rightarrow$ NH$_2$HgOHgI (Iodide of millon’s base, brown ppt) + KCl + H$_2$O

Chromium oxide powder is green

Bismuth oxide is Yellow

KI Potassium Iodide is white
Tin reacts with conc. HNO₃ forming metastannic acid (H₂SnO₃).
Tin is not attacked by organic acids and hence is used for tinning of utensils to resist corrosion. Tin foils are used for wrapping cigarettes, confectionary items and for making tooth-paste tubes.
SnO₂ is an amphoteric oxide.
Stannous chloride (SnCl₂) acts as a good reducing agent. It reduces HgCl₂ to first Hg₂Cl₂ and then to Hg.
It also reduces FeCl₃ to FeCl₂.
Stannic chloride (SnCl₄) is a liquid and fumes in air due to hydrolysis. It acts as a Lewis acid and dissolves in concentrated HCl forming H₂SnCl₆.
SnCl₄.5H₂O is called butter of tin.
SnS dissolves in yellow ammonium sulphide.

Aluminum Oxide is white

Mercuric Iodide Hgl₂: It is a yellow solid below 400K but changes to red solid above 400K.

\[
\text{Hgl}_2 \xrightarrow{400K} \text{Hgl}_2
\]

It dissolves in excess of KI forming K₂Hgl₄;
Hgl₂ + 2KI → K₂Hgl₄
Alkaline solution of K₂Hgl₄ is called Nessler’s reagent.
Add NH₄OH excess and dimethylglyoxime to NiCl₂ then a rosy red ppt of nickel appears

\[
\text{CuO} + \text{B₂O₃ (Glassy bead)} \rightarrow \text{Cu(BO₂)₂ (Copper metabolite - blue)}
\]

**Compounds of zinc**

**Zinc oxide** ZnO: Zincite (ZnO) is also called Philosopher’s wool. It is a white powder, becomes yellow on heating and again white on cooling. It is amphoteric in nature. It is used as a white pigment under the name Zinc white or Chinese white.

**Zinc Sulphate** (white vitriol), ZnSO₄·7H₂O: It is a colourless transparent crystal highly soluble in water. It is used as an eye-lotion and for preparing double salts. On heating it loses its molecules of water as,

\[
\begin{align*}
\text{ZnSO₄·7H₂O} & \xrightarrow{375K} \text{ZnSO₄·H₂O} \xrightarrow{725K} \text{ZnSO₄} \\
& \xrightarrow{1075K} \text{ZnO} + \text{SO₂} + \text{O₂}
\end{align*}
\]
Verdigris - basic copper acetate

This pigment was used in the Middle Ages in paints. Until the nineteenth century, this was the most vibrant shade of green available and it was used by artists widely. The color comes from copper acetate and you should know that it is highly toxic to humans.

Compounds of Mercury

(1) Mercuric oxide, \( \text{HgO} \): It is obtained as a red solid by heating mercury in air or oxygen for a long time at 673 K

\[
2\text{Hg} + \text{O}_2 \rightarrow 2\text{HgO} \text{ (red)} \text{ or by heating mercuric nitrate alone or in the presence of Hg}
\]

\[
\text{Heat}
\]

\[
2\text{Hg ( NO}_3\text{ )}_2 \rightarrow 2\text{HgO} + 4\text{NO}_2 + \text{O}_2
\]

\text{red}
When NaOH is added to a solution of HgCl$_2$, yellow precipitate of HgO are obtained.

\[
\text{Hg}_2\text{Cl}_2 + 2\text{NaOH} \rightarrow \text{HgO} \downarrow + \text{H}_2\text{O} + 2\text{NaCl}
\]

( Yellow )

Red and yellow forms of HgO differ only in their particle size. On heating to 673 K, yellow form changes to red form.

It is used in oil paints or as a mild antiseptic in ointments.

(2) Mercuric chloride, HgCl$_2$: It is obtained by treating Hg with Cl$_2$ or by heating a mixture of NaCl and HgSO$_4$ in presence of small amount of MnO$_2$ (which oxidizes any Hg(I) salts formed during the reaction).

Heat

\[
\text{HgSO}_4 + 2\text{NaCl} \rightarrow \text{HgCl}_2 + \text{Na}_2\text{SO}_4
\]

MnO$_2$
HgCl₂ is a white crystalline solid and is commonly known as corrosive sublimate. It is a covalent compound since it dissolves in organic solvents like ethanol and ether.

It is extremely poisonous and causes death. Its best antidote is white of an egg.

When treated with stannous chloride, it is first reduced to white ppt. of mercurous chloride and then to mercury (black).

$$2\text{HgCl}_2 + \text{SnCl}_2 \rightarrow \text{Hg}_2\text{Cl}_2 + \text{SnCl}_4$$

white ppt.

$$\text{Hg}_2\text{Cl}_2 + \text{SnCl}_2 \rightarrow 2\text{Hg} + \text{SnCl}_4$$

grey

With ammonia it gives a white ppt. known as infusible white ppt.

$$\text{HgCl}_2 + 2\text{NH}_3 \rightarrow \text{Hg} (\text{NH}_2) \text{Cl} + \text{NH}_4 \text{Cl}$$ A dilute solution of HgCl₂ is used as an antiseptic. (3) Mercuric iodide, Hgl₂: It is obtained when a required amount of KI solution is added to a solution of HgCl₂. HgCl₂HgCl₂ + 2KI → Hgl₂ + 2KCI (red) Below 400 K, Hgl₂ is red but above 400 K, it turns yellow

$$\text{Hgl}_2 \text{ red complex ion.} \text{HgCl}_2 + 2\text{KI} \rightarrow K_2\text{Hgl}_4 \text{ Red ppt.}$$ soluable colourless solution

An alkaline solution of K₂ [Hgl₄] is called Nessler’s reagent and is used to test NH₄⁺ ions.

It gives a brown ppt. of NH₂ - Hg - O Hg - I (Iodide of Millon’s base) with NH₄⁺ ions.

$$2K_2 \text{[Hgl}_4 \text{]} + \text{NH}_3 + 3\text{KOH} \rightarrow \text{NH}_2 \cdot \text{HgO. Hgl + 7KI + 2H}_2 \text{O}$$

It is used in ointments for treating skin infections.

(4) Mercurous chloride, Hg₂Cl₂: It is obtained as under:

(a) Hg₂ (NO₃) + 2NaCl → Hg₂Cl₂ + 2NaNO₃

white ppt.

Heat in an iron retort
(b) \( \text{HgCl}_2 + \text{Hg} \rightarrow \text{Hg}_2 \text{Cl}_2 \) (condenses on cooling)

It is purified by sublimation.

Mercurous chloride is also called calomel. It is a white powder insoluble in \( \text{H}_2\text{O} \). On heating, it decomposes to give \( \text{HgCl}_2 \) and \( \text{Hg} \).

\[
\text{Heat} \quad \text{Hg}_2 \text{Cl}_2 \quad \rightarrow \quad \text{HgCl}_2 + \text{Hg}
\]

It dissolves in chlorine water forming mercuric chloride.

\[
\text{Hg}_2\text{Cl}_2 + \text{Cl}_2 \rightarrow 2\text{HgCl}_2
\]

With ammonia, it turns black due to the formation of a mixture of finely divided black \( \text{Hg} \) and mercuric amino chloride.

\[
\text{Hg}_2\text{Cl}_2 + 2\text{NH}_3 \rightarrow \text{Hg} + \text{NH}_2\text{HgCl} + \text{NH}_4\text{Cl}
\]

(black)

It is used to prepare standard calomel electrode and as a purgative in medicine.

(5) Mercuric sulphide, \( \text{HgS} \): The solubility product of \( \text{HgS} \) is lower than that of \( \text{ZnS} \) and hence it gets precipitated as black solid when \( \text{H}_2\text{S} \) is passed through an acidic solution of any mercury (II) salt.

\[
\text{HgCl}_2 + \text{H}_2\text{S} \rightarrow \text{HgS} + 2\text{HCl}
\]

It is insoluble in water and \( \text{HCl} \) but dissolves in aqua regia (1 part conc.\( \text{HNO}_3 \) + 3 parts conc. \( \text{HCl} \))

\[
3\text{HCl} + \text{HNO}_3 \rightarrow \text{NOCl} + 2\text{H}_2\text{O} + 2 \left\{ \text{Cl} \right\}
\]

Aqua regia Nitrosyl chloride Nacent chlorine

\[
\text{HgS} + 2\left\{ \text{Cl} \right\} \rightarrow \text{HgCl}_2 + \text{S} \downarrow
\]

(Soluble)

On sublimation, its colour changes to red and hence it is used as a red pigment.

(6) Mercuric sulphate, \( \text{HgSO}_4 \): It is obtained when \( \text{HgS} \) is treated with conc.\( \text{H}_2\text{SO}_4 \).

\[
\text{Hg} + 2\text{H}_2\text{SO}_4 \rightarrow \text{HgSO}_4 + \text{SO}_2 + 2\text{H}_2\text{O}
\]

It is a white solid which decomposes on heating to give mercurous sulphate.

\[
3\text{HgSO}_4 \xrightarrow{\Delta} \text{Hg}_2\text{SO}_4 + \text{Hg} + 2\text{SO}_2 + 2\text{O}_2
\]
It is used as a catalyst in the hydration of alkynes to give aldehydes or ketones. It is also used as a cosmetic under the name Vermillion and in ayurvedic medicine as makardhwaj.

(7) Amalgams : Mercury forms alloys commonly known as amalgams, with all metals except iron and platinum. Hence it is transported in iron containers.

(8) Alloy of transition metal : See in table discuss earlier in metallurgy.

The common Anions are divided into 3 groups for the purpose of identification:

Those which evolve gases with dilute hydrochloric acid:
- Carbonate (CO$_3^{2-}$)
- Bicarbonate(HCO$_3^-$)
- Nitrite(NO$_2^-$)
- Sulphide (S$^{2-}$)
- Sulphite(SO$_3^{2-}$)
- Thiosulphate(S$_2$O$_3^{2-}$)

Those which do not react with dilute HCl, but which do evolve gases or volatile liquids with concentrated sulphuric acid:
- Chloride (Cl$^-$)
- Bromide (Br$^-$)
- Iodide (I$^-$)
- Nitrate (NO$_3^-$)

Those which do not react with either dilute hydrochloric acid or concentrated sulphuric acid:
- Phosphate (PO$_4^{3-}$)
- Borate (B$_4$O$_7^{2-}$)
- Sulphate (SO$_4^{2-}$)

A Radical is an atom, or group of atoms that behaves like a single atom. Examples : H, K, Na, Cu, Pb, simple radicals ; NH$^4$, SO$^2$, NO$^2$, compound
radicals.

A Basic Radical is a metal, or any radical behaving like a metal. Examples: Ag, Cu, Ca, Na, and NH4 the last so classified because it behaves like such simple radicals as Na, K, and Li.

An Acid Radical is a nonmetal, or any radical behaving like a nonmetal. Examples: Cl, Br, I, SO2, NO2

An Acid is a substance containing H that may be replaced by a basic radical. When a nonmetal is combined with H only, as in HCl, HBr, H2S, the compound is said to be a binary (i.e. composed of two elements) acid, or an hydracid. When the nonmetal is combined with H and O, the compound is called a ternary (i.e. composed of three or more elements) acid, or an oxyacid; and the characteristic name of the acid is formed by adding the termination -ic to the name of the nonmetal to denote more oxygen, or the termination -ous to denote less. Examples: H2SO4 sulphuric, and H2SO3 sulphurous acid.

These are classified in six different groups in accordance with certain properties which permit a group precipitation by a single reagent. A reagent used for precipitation of a whole group is called a general reagent.

A reagent used as a test for a single substance is known as a special reagent.

Experiments showing Method of Classification

Use the following solutions: AgNO3, Cu(NO3)2, AsCl3, Fe2Cl6, Co(N03)2, Ba(N03)2, NaCl.

Take about 2 c.c. of each solution, and add HCl.*

Points to be Observed Whether a precipitate is formed.

Whether the precipitate is soluble in an excess of the reagent.

* Always use dilute acids unless otherwise directed.

GROUPING THE BASES

The color of each precipitate.

Whether there is change in color of the precipitate.

Change in color of solutions.

Chemical equations.

Tabulate all results carefully in your notebook, according to the following scheme:

HC1 was added to the seven solutions with the following results:
Typical of Gr. I  
\[ \text{AgNO}_3 + \text{HCl} = \text{AgCl} \text{ w. pp.} + \text{IN} \]  
Typical of Gr. II A  
\[ \text{Cu(NO}_3\text{)}_2 + \text{II Cl} = \text{No change.} \]
Typical of Gr. II B  
\[ \text{AsCl}_3 + \text{HCl} = \text{No change.} \]
Typical of Gr. III  
\[ \text{Fe}_2 \text{Cl}_6 + \text{HCl} = \text{No change.} \]
Typical of Gr. IV  
\[ \text{Co(NO}_3\text{)}_2 + \text{IICl} = \text{No change.} \]
Typical of Gr. V  
\[ \text{Ba(NO}_3\text{)}_2 + \text{HCl} = \text{No change.} \]
Typical of Gr. VI  
\[ \text{NaCl} + \text{HCl} = \text{No change.} \]

### 1) Anions which react with dilute hydrochloric acid

<table>
<thead>
<tr>
<th>Carboneates (CO(_3)(^2))</th>
<th>Bicarbonate (HCO(_3))</th>
<th>Nitrates (NO(_3)(^-))</th>
</tr>
</thead>
<tbody>
<tr>
<td>All carbonates except those of alkali metals, and ammonium are very slightly or difficult soluble in water. Accordingly reactions in solution are only carried out in case of the soluble salts.</td>
<td>All bicarbonates are water soluble.</td>
<td>Most nitrates are water soluble except that of silver.</td>
</tr>
</tbody>
</table>

### Solid salt + dil. HCl

<table>
<thead>
<tr>
<th>Solid salt + dil. HCl</th>
<th>Effervescence and a colourless gas is evolved. Carbon dioxide (CO(_2)).</th>
<th>Effervescence and a colourless gas is evolved. Carbon dioxide (CO(_2)).</th>
<th>Pentagonal brown fumes are evolved consisting mainly of nitrogen dioxide (NO(_2)). which is produced by the combination of nitric oxide (NO) with the oxygen of the air:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Na(_2)CO(_3) + 2HCl</td>
<td>Na(_2)Cl + 2H(_2)O + CO(_2).</td>
<td>Na(_2)HCO(_3) + HCl = Na(_2)Cl + H(_2)O + CO(_2).</td>
<td>N(_2)O(_5) + H(_2)O → 2NO(_2) + H(_2)O</td>
</tr>
</tbody>
</table>

### To differentiate between CO\(_3\)\(^2\) and HCO\(_3\)

<table>
<thead>
<tr>
<th>Carbonate</th>
<th>Bicarbonate</th>
<th>Nitrates</th>
</tr>
</thead>
<tbody>
<tr>
<td>1) Salt solution + magnesium sulphate solution</td>
<td>White precipitate of magnesium carbonate</td>
<td>No ppt. in the cold, as magnesium bicarbonate is soluble, but on heating, a white ppt. of magnesium carbonate is obtained:</td>
</tr>
<tr>
<td>Na(_2)CO(_3) + MgSO(_4) → MgCO(_3)↓ + Na(_2)SO(_4)</td>
<td>2NaHCO(_3) + MgSO(_4) → Na(_2)SO(_4) + Mg(HCO(_3))↓</td>
<td>2NaHCO(_3) + MgSO(_4) + water</td>
</tr>
<tr>
<td>2) Salt solution + mercuric chloride solution</td>
<td>Reddish brown precipitate of mercuric carbonate</td>
<td>No ppt. in the cold, but on heating a reddish brown ppt. of mercuric carbonate is obtained:</td>
</tr>
<tr>
<td>Na(_2)CO(_3) + HgCl(_2) → HgCO(_3)↓ + 2NaCl</td>
<td>2NaHCO(_3) + HgCl(_2) → 2NaCl + Hg(HCO(_3))↓</td>
<td>2NaHCO(_3) + HgCl(_2) + water</td>
</tr>
</tbody>
</table>

1) **Brown ring test:**
- To a dilute solution of the nitrite, add two drops of freshly prepared ferric nitrate solution (Fe(NO\(_3\))\(_3\)), and then add dil. H\(_2\)SO\(_4\) very carefully drop by drop down the inside of the test tube. a brown ring forms due to the formation of Fe(NO\(_3\))SO\(_4\). |
- Note: If the addition of a dil. H\(_2\)SO\(_4\) is not down the inside of the test tube, the solution becomes brown color (we can not note the ring).

2) **Solution of nitrite + potassium iodide solution (KI) = dilute sulfuric acid :** A pale brown color appears due to the liberation of iodine. (The nitrite solution is an oxidizing agent.)

3) **Solution of nitrite : acidified solution of potassium permanganate:** The purple colour of the permanganate disappears (the nitrite solution is a reducing agent)
Is HgCO₃ reddish Brown?

<table>
<thead>
<tr>
<th>Sulphites (SO₃²⁻)</th>
<th>Thiosulphates (S₂O₃²⁻)</th>
<th>Sulpfides (S²⁻)</th>
</tr>
</thead>
<tbody>
<tr>
<td>All sulphates are slightly soluble in water except the alkali metal sulphates and the ammonium salt.</td>
<td>Sodium thiosulphate is readily soluble in water, other thiosulphates are slightly soluble.</td>
<td>All sulphides, except those of alkali, alkali earth metals and the ammonium ion are slightly soluble in water.</td>
</tr>
</tbody>
</table>

**Solid salt + dilute HCl**

Sulphur dioxide gas (SO₂) is evolved, which is recognizable by its pungent smell.

\[ \text{Na}_2\text{SO}_3 + 2\text{HCl} \rightarrow 2\text{NaCl} + \text{H}_2\text{O} + \text{SO}_2 \]

Test for sulphur dioxide:

Dip a small piece of paper into an acidic solution of potassium dichromate, and hold it over the mouth of the test tube. The paper will turn green, because the sulphur dioxide reduces the dichromate to a chromic sulphate.

\[ 3\text{SO}_2 + \text{K}_2\text{Cr}_2\text{O}_7 + \text{H}_2\text{SO}_4 \rightarrow \text{K}_2\text{SO}_4 + \text{Cr}_2(\text{SO}_4)_3 + \text{H}_2\text{O} \]

Orange Green

| Colourless gas with pungent odour, which turns an acidified potassium dichromate paper green, is evolved (SO₂), and a yellow precipitate of sulphur (S) appears. |

| Colourless gas, hydrogen sulphide (H₂S), is evolved which is recognizable by its bad smell. |

| Na₂S + 2HCl → 2NaCl + H₂S |

Test for hydrogen sulphide:

Dip a piece of paper in a solution of lead nitrate, and hold it over the mouth of the test tube in which the H₂S is being generated.

The paper will turn black due to the formation of lead sulphide.

| H₂S + Pb(CH₃COO)₂ → PbS + 2CH₃COOH Black |

K₂SO₄ is white

Cr₂(SO₄)₃ is green
| Confirmation tests: | 1) Salt solution + silver nitrate solution (AgNO₃): A white precipitate forms (silver sulphate, Ag₂SO₄) which dissolves in excess of sulphite due to the formation of soluble complex.

   \[ \text{Na}_2\text{SO}_3 + 2\text{AgNO}_3 \rightarrow \text{Ag}_2\text{SO}_4 + 2\text{NaNO}_3 \]  

   RS  

   \[ \text{Ag}_2\text{SO}_4 + \text{Na}_2\text{SO}_3 \rightarrow 2\text{Na}[\text{AgSO}_3] \text{ Soluble complex.} \]  

2) Salt solution + lead acetate solution (Pb(CH₃COO)₂): A white ppt of lead sulphite (PbSO₃) is formed.

   \[ \text{Na}_2\text{SO}_3 + \text{Pb}(\text{CH}_3\text{COO})_2 \rightarrow \text{PbSO}_3 \downarrow + 2\text{CH}_3\text{COONa} \]  

   RS  

   A white ppt of lead thiosulphate (PbS₂O₃₂) is formed, the ppt turns black (PbS) on boiling.

   \[ \text{Na}_2\text{SO}_3 + \text{Pb}(\text{CH}_3\text{COO})_2 \rightarrow \text{PbS}_2\text{O}_3\text{₂} + 2\text{CH}_3\text{COONa} \]  

   White ppt  

   \[ \text{PbS}_2\text{O}_3\text{₂} + \text{H}_2\text{O} \rightarrow \text{PbS}_↓ + \text{H}_2\text{SO}_₃ \]  

   Black ppt  

   "Salt solution + drops of acidified solution of K₂MnO₄: The purple colour of the permanganate will disappear. The sulphite reduces the permanganate ion (MnO₄²⁻) which is almost colourless.

   \[ 5\text{Na}_2\text{SO}_3 + 2\text{KMnO}_4 + 3\text{H}_2\text{SO}_₄ \rightarrow 5\text{Na}_2\text{SO}_₄ + 2\text{K}_2\text{SO}_₄ + 2\text{MnSO}_₄ + 3\text{H}_2\text{O} \]  

*Salt solution + Sodium nitroprusside solution: A violet colour is formed.

<table>
<thead>
<tr>
<th>Sulphites</th>
<th>Thiosulphates</th>
</tr>
</thead>
</table>
| **Salt solution + 2 drops of dil. H₂SO₄ + Iodine solution(ℓ):** The brown colour of the iodine solution disappears.

   \[ \text{Na}_2\text{SO}_₃ + \text{I}_₂ + \text{H}_₂\text{O} \rightarrow \text{Na}_2\text{SO}_₄ + 2\text{HI} \]  

   | The brown colour of the iodine solution disappears because the iodine is reduced to the iodide ion, which is colourless. At the same time, the thiosulphate is oxidized to tetrathionate:

   \[ 2\text{Na}_2\text{S}_₂\text{O}_₄ + \text{I}_₂ \rightarrow \text{Na}_₂\text{S}_₄\text{O}_₆ + 2\text{NaI} \]  

CBSE Standard 12 Chemistry Survival Guide - Reduction Methods by Prof. Subhashish Chattopadhyay
SKMClasses Bangalore Useful for IIT-JEE, I.Sc. PU-II, Boards, IGCSE IB AP-Chemistry and other exams
### 2) Anions which react with concentrated sulphuric acid

**Note:** Do these tests in fuming room because the gases which are given off in these tests are extremely irritating and can cause damage to the sensitive mucous membranes of nose and throat.

<table>
<thead>
<tr>
<th>Chlorides (Cl⁻)</th>
<th>Bromides (Br⁻)</th>
<th>Iodides (I⁻)</th>
<th>Nitrates (NO₃⁻)</th>
</tr>
</thead>
<tbody>
<tr>
<td>All chlorides are water soluble except the chlorides of silver, mercuric and cuprous.</td>
<td>Bromides resemble chlorides in their solubility.</td>
<td>Iodides resemble chlorides and bromides in their solubility. However, bismuth iodide is insoluble.</td>
<td>All nitrates are soluble in water except some basic nitrates.</td>
</tr>
</tbody>
</table>

**Solid salt + conc. H₂SO₄:**

- **Effervescence with evolution of colourless gas.** Hydrogen chloride (HCl).
- \(2\text{NaCl} + \text{H}_2\text{SO}_4 \rightarrow \text{Na}_2\text{SO}_4 + 2\text{HCl}\)

**Test for HCl gas:**

Dip a clean glass rod into a bottle of concentrated ammonia solution, and hold it close to the mouth of the test tube in which the HCl is being produced. Dense white fumes of ammonium chloride will be formed: \(\text{HCl} + \text{NH}_3 \rightarrow \text{NH}_4\text{Cl}\)

- **Reddish fumes evolve and the solution turns orange due to liberation of bromine (Br₂).**
- \(2\text{NaBr} + \text{H}_2\text{SO}_4 \rightarrow 2\text{HBr} + \text{Na}_2\text{SO}_4\)
- \(2\text{HBr} + \text{H}_2\text{SO}_4 \rightarrow 2\text{H}_2\text{O} + \text{SO}_2 + \text{Br}_2\)

**If a small piece of copper metal and drops of water are added, dense brown fumes of nitrogen dioxide (NO₂) will be given off.**

If no result, heat carefully:
- \(2\text{KNO}_2 + \text{H}_2\text{SO}_4 \rightarrow \text{K}_2\text{SO}_4 + 2\text{H}_2\text{O} + \text{NO}_2 + \text{O}_2\)
- \(\text{HNO}_3 + \text{Cu} \rightarrow \text{Cu(NO}_3)_2 + 2\text{H}_2\text{O} + 2\text{NO}_2\)

### Confirmation tests

<table>
<thead>
<tr>
<th>Chlorides</th>
<th>Bromides</th>
<th>Iodides</th>
<th>Nitrates</th>
</tr>
</thead>
</table>

1) **Salt solution + silver nitrate (AgNO₃):**

- A dense white ppt of silver chloride (AgCl) slowly turns a yellowish green due to decomposition.
- \(\text{NaCl} + \text{AgNO}_3 \rightarrow \text{AgCl} + \text{NaNO}_3\)

2) **Salt solution + lead acetate (Pb(CH₃COO)₂):**

- A white precipitate of lead chloride (PbCl₂) appears which is soluble in boiling water and recrystallizes on cooling.
- \(2\text{NaBr} + \text{Pb(CH}_3\text{COO)}_2 \rightarrow \text{PbBr}_2 \downarrow + 2\text{CH}_3\text{COONa}\)

### Other tests

- **Sodium solution + mercury chloride (HgCl₂):**
  - A reddish precipitate of mercury iodide (HgI₂) is formed which dissolves in excess of KI.
  - \(\text{HgCl}_2 + 2\text{KI} \rightarrow \text{HgI}_2 + 2\text{KCl}\)
  - **Brown ring test:** The nitrate solution is mixed with freshly prepared FeSO₄ solution, then conc. H₂SO₄ is added and allowed to flow cautiously on the side of the test tube. A brown ring (Fe₂(NO₃)₃) is formed at the interface of the two layers. The brown ring disappears on shaking the solution.
AgCl is white

Cul Cuprous Iodide

Brown Ring Test
BaSO₄ is white

<table>
<thead>
<tr>
<th>Phosphates (H₃PO₄, H₂PO₄⁻, HPO₄²⁻)</th>
<th>Borates (BO₃³⁻, BO₂⁻, B₂O₄⁻)</th>
<th>Sulphates (SO₄²⁻)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Most phosphates are insoluble in water except those of ammonium and alkali metals.</td>
<td>Ammonium and alkali metal borates are water soluble while other borates are slightly soluble in water.</td>
<td>All sulphates are soluble in water except those of some divalent metals e.g. calcium, strontium, barium and lead.</td>
</tr>
<tr>
<td><strong>Salt solution + Barium chloride solution (BaCl₂)</strong></td>
<td>A white precipitate of barium phosphate (Ba₃(PO₄)₂) is produced, soluble in dilute acids e.g. HNO₃ or HCl and insoluble in excess of barium chloride.</td>
<td>A white precipitate of barium sulphate (BaSO₄) is formed which is insoluble in dilute acids and in excess of barium chloride.</td>
</tr>
<tr>
<td>Na₂HPO₄ + BaCl₂ → Ba₃(PO₄)₂↓ + 2NaCl</td>
<td>Na₂₃BO₃ + 3H₂O + BaCl₂ → Ba(BO₂)₂↓ + 2H₂BO₃ + 2NaCl</td>
<td>Na₂SO₄ + BaCl₂ → BaSO₄↓ + 2NaCl</td>
</tr>
<tr>
<td><strong>Confirmatory tests:</strong></td>
<td><strong>A yellow precipitate of silver phosphate (Ag₃PO₄) is formed, which is readily soluble in dil. HNO₃ and ammonia.</strong></td>
<td><strong>A white precipitate of silver sulphate (Ag₂SO₄) is formed with concentrated solution.</strong></td>
</tr>
<tr>
<td>1) Salt solution + silver nitrate (AgNO₃)</td>
<td>A white ppt. of silver borate (Ag₂BO₂) is formed, from concentrated solution, which give brown ppt. after boiling (also a brown ppt. is formed with dilute solution).</td>
<td>Na₂SO₄ + 2AgNO₃ → Ag₂SO₄↓ + 2NaNO₃</td>
</tr>
<tr>
<td>Na₃BO₃ + 3H₂O + 2AgNO₃ → 2AgBO₃ + 2NaNO₃ + 3H₂O</td>
<td>2AgBO₃ + 3H₂O → Ag₂O + 2H₂BO₃</td>
<td></td>
</tr>
</tbody>
</table>
### For phosphates:

0.5 ml of salt solution + 1 ml of ammonium molybdate solution + 0.5 ml of conc. HNO₃

Form a canary yellow precipitate of ammonium phosphomolybdate (NH₄)₂Mo₄O₁₂·H₂O in the cold or by gentle warming.

(Uses the volume needed in this test).

### For sulphates:

**Salt solution – lead acetate:**

A white precipitate of lead sulphate is formed, which is readily soluble in hot concentrated ammonium acetate or conc. H₂SO₄.

- K₂SO₄ + Pb(CH₃COO)₂ → PbSO₄ + 2CH₃COOK
- PbSO₄ + H₂SO₄ → Pb(HSO₄)₂
### Scheme for the identification of acid radicals

<table>
<thead>
<tr>
<th>Observation</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Effervescence and a colourless gaseous gas is evolved.</td>
<td>The gas is CO₂. The anion is carbonate or bicarbonate.</td>
</tr>
<tr>
<td>Pungent brown fumes are evolved.</td>
<td>The gas is NO₂. The anion is Nitrate.</td>
</tr>
<tr>
<td>Colourless gas with Pungent odor, which turns an acidified dichromate paper green, is evolved.</td>
<td>The gas is SO₂ and the green colour is Cr₂(SO₄)³⁻. The anion is sulphite.</td>
</tr>
<tr>
<td>Colourless gas with pungent odour, which turns an acidified potassium dichromate paper green, is evolved, and a yellow precipitate of sulphur appears.</td>
<td>The gas is SO₃. The ppt. is S and the green colour is Cr₂(SO₄)³⁻. The anion is thiosulphate.</td>
</tr>
<tr>
<td>Colourless gas is evolved which is characterized by its bad odour and turning a lead acetate paper black.</td>
<td>The gas is H₂S and the black colour is PbS. The anion is sulphydrate.</td>
</tr>
</tbody>
</table>

To differentiate between carbonate and bicarbonate:

1) Salt solution - magnesium sulphate solution:
- **For carbonate:** White precipitate of magnesium carbonate (MgCO₃).
- **For bicarbonate:** No ppt in the cold, but on heating, a white ppt of magnesium carbonate is obtained.

2) Solid salt + conc. H₂SO₄:
- **Observation:** Effervescence with the evolution of a colourless gas which forms white fumes with NH₃OH.
- **Results:** The gas is HCl and the white fumes are NH₄Cl. The anion is chloride.

3) Salt solution - BaCl₂:
- **Observation:** A white precipitate is produced, soluble in dilute acids e.g. HNO₃ or HCl and insoluble in excess of barium chloride.
- **Results:** The white precipitate is barium phosphate (BaPO₄). The anion is phosphate.

### Notes
- If a small piece of copper metal and drops of water are added, dense brown fumes will be given off. If no results, heat carefully. If any are obtained, test with conc. H₂SO₄.
- The salt does not react with conc. H₂SO₄.
- The salt does not react with dil. HCl.
To differentiate between phosphate, borate and sulphate:

Salt solution + AgNO₃ (silver nitrate):

<table>
<thead>
<tr>
<th>Observation</th>
<th>phosphate</th>
<th>borate</th>
<th>Sulphate</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>A yellow precipitate is formed, which is ready</td>
<td>A white ppt. is formed from concentrated</td>
<td>A white ppt. is formed, with concentrated</td>
</tr>
<tr>
<td></td>
<td>soluble in dil. HNO₃ and ammonia.</td>
<td>solution, which gives brown ppt. after</td>
<td>solution.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>boiling (also, a brown ppt. is formed</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>with diluted solution.)</td>
<td></td>
</tr>
</tbody>
</table>

| Results           | The yellow ppt. is silver phosphate (Ag₃PO₄).  | The white ppt. is silver borate (AgBO₂).   | The white ppt. is silver sulphate (Ag₂SO₄).   |
|                   | The anion is phosphate.                         | The anion is borate.                        | The anion is sulphate.                        |
# Oxidation States and Colors

<table>
<thead>
<tr>
<th>Metal</th>
<th>+1</th>
<th>+2</th>
<th>+3</th>
<th>+4</th>
<th>+5</th>
<th>+6</th>
<th>+7</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sc</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Colorless</td>
</tr>
<tr>
<td>Ti</td>
<td>Violet</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Colorless</td>
<td></td>
</tr>
<tr>
<td>V</td>
<td>Violet</td>
<td>Green</td>
<td>blue</td>
<td>Yellow</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cr</td>
<td>Blue</td>
<td>Green</td>
<td></td>
<td>Yellow (CrO$_2^-$) orange (Cr$_2$O$_7^{2-}$)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mn</td>
<td>Pale pink</td>
<td>Brown</td>
<td></td>
<td>Dark green (MnO$_2$) Intense purple (MnO$_4^-$)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fe</td>
<td>Pale green</td>
<td>Yellow or brown</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Co</td>
<td>Pink</td>
<td>Orange/yellow</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ni</td>
<td>Green</td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Cu</td>
<td>Blue</td>
<td></td>
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<tr>
<td>Zn</td>
<td>colorless</td>
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</tbody>
</table>
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