Chapter 17

Properties and Applications of Ruthenium

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Abstract

Ruthenium (Ru) with atomic number of 44 is one of the platinum group metals, the others being Rh, Pd, Os, Ir and Pt. In earth's crust, it is quite rare, found in parts per billion quantities, in ores containing some of the other platinum group metals. Ruthenium is silvery whitish, lustrous hard metal with a shiny surface. It has seven stable isotopes. Recently, coordination and organometallic chemistry of Ru has shown remarkable growth. In this chapter, we review the application of Ru in diverse fields along with its physical and chemical properties. In the applications part of Ru we have primarily focused on the biomedical applications. The biomedical applications are broadly divided into diagnostic and treatment aspects. Ru and their complexes are mainly used in determination of ferritin, calcitonin and cyclosporine and folate level in human body for diagnosis of diseases. Treatment aspects focuses on immunosuppressant, antimicrobial and anticancer activity.

Keywords: ruthenium, platinum group, biomedical application, rare element, cancer, isotopes

1. Discovery of ruthenium

Ruthenium is one of the 118 chemical elements given in the periodic table. Out of these 118 elements, 92 elements originated from natural sources and remaining 26 elements have been synthesized in laboratories [1, 2]. The last naturally occurring element to be discovered was Uranium in 1789 [1, 3]. Technetium was the first man-made element to be synthesized in the year 1937 [2]. Recently in the year 2016, four of the man-made elements were included in periodic table. The four newly added elements goes by the name nihonium (Nh), moscovium (Mc), tennessine (Ts), and oganesson (Og), respectively for element 113, 115, 117 and 118 [4].

Discovery of Ruthenium had many twist and turns. A polish Chemist Jedrzej Sniadecki (1768–1838) in 1808 was first to announce the discovery of an element which he named Vestium after an asteroid called Vesta [3]. However, none of the contemporary Chemists were able to confirm his discovery. Later he again reported discovery of element 44 while working on the platinum ores from South America and published his results but again none of the fellow chemist were able to confirm the element 44 [4]. Due to repeated failures of his claim, Sniadecki got depressed and dropped the idea of further research on this element [1, 5]. After 20 years, a Russian chemist, Gottfried W. Osann, claimed the discovery of element 44. His discovery had the same fate as that of Sniadecki as none of his fellow chemist could repeat his results [5].

At last in the year 1844, another Russian chemist Carl Ernst Claus [also known in Russian as Karl Karlovich Klaus (1796–1864)] tried his luck on discovery of element 44. He succeeded in it as he gave positive proof about the new element extracted from platinum ores obtained from the Ural Mountains in Russia [6]. Claus had suggested the name of newly discovered element as Ruthenium after the name Ruthenia which was the ancient name of Russia. Earlier Osann had also suggested the same name for the element 44 [2, 5]. Ruthenium with atomic number 44 was given the symbol Ru. It is included in group 8, period 5 and block d in modern periodic table and it is a member of the platinum group metals [5].

2. Occurrence in nature

Like other platinum group metals, Ruthenium is also one of the rare metals in the earth's crust. It is quite rare in that it is found as about 0.0004 parts per million of earth crust [6]. This fraction of abundance makes it sixth rarest metal in earth crust. As other platinum group metals, it is obtained from platinum ores [7]. For instance, it is also obtained by purification process of a mineral called osmiridium [5].

3. Electronic configuration of Ru

In the modern periodic table, group 8 consists of four chemical elements. These elements are Iron (Fe), Ruthenium (Ru), Osmium (Os) and Hassium (Hs) [7]. Ruthenium has atomic number of 44, that is, it contains 44 electrons distributed in atomic orbitals and its nucleus has 44 protons and 57 neutrons (**Figure 1**). Electron distribution in atomic or molecular orbitals is called electron configuration which for Ru and the other group 8 chemical elements is shown in **Table 1**. Except for Ru, the electron configuration of group 8 elements shows two electrons in their outer most shell; Ruthenium has only one electron in its outermost shell. This tendency is quite similar to its neighboring metals such as niobium (Nb), molybdenum (Mo) and rhodium (Rh) [8].

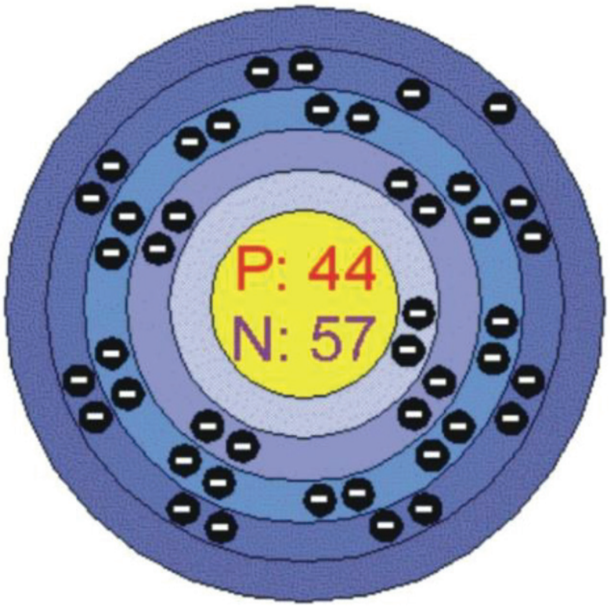

Figure 1. Schematic of the electron configuration and nucleus of an atom of Ruthenium.

Atomic number	Element	Electron configuration	Number of electrons per shell
26	Iron (Fe)	$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2\ 3d^6$	2,8,14,2
44	Ruthenium (Ru)	$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2\ 3d^{10}\ 4p^6\ 5s^1\ 4d^7$	2,8,18,15,1
76	Osmium (Os)	$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2\ 3d^{10}\ 4p^6\ 5s^2\ 4d^{10}\ 5p^6\ 6s^2\ 4f^{14}\ 5d^6$	2,8,18,32,14,2
108	Hassium (Hs)	$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2\ 3d^{10}\ 4p^6\ 5s^2\ 4d^{10}\ 5p^6\ 6s^2\ 4f^{14}\ 5d^{10}\ 6p^6\ 7s^2\ 5f^{14}\ 6d^6$	2,8,18,32,32,14,2

Table 1. Electron configuration of group 8 chemical elements.

4. Isotopes of Ru

Any atom having same number of protons, but different number of neutrons is termed as an Isotope. Isotopes can be differentiated on the basis of mass number as each isotope consists of different mass number which is being written on the right of the element name [1, 7]. Mass number indicates sum total of proton and neutron present in the nucleus of atom [9]. Ruthenium has many isotopes although only seven of them are stable. Apart from seven stable isotopes, 34 radioactive isotopes of Ruthenium are also found [8]. The most stable radioactive isotopes are ^{106}Ru, ^{103}Ru, ^{97}Ru having a half-life of 373.59, 39.26, 2.9 days, respectively. Other characteristics of the main isotopes are listed in **Table 2** [8].

Main isotopes of Ruthenium			
S. No.	**Isotopes**	**Abundance**	**Half-life**
1	^{96}Ru	5.54%	Stable with 52 neutrons
2	^{97}Ru	Synthetic	2.9 days
3	^{98}Ru	1.87%	Stable with 54 neutrons
4	^{99}Ru	12.76%	Stable with 55 neutrons
5	^{100}Ru	12.60%	Stable with 56 neutrons
6	^{101}Ru	17.06%	Stable with 57 neutrons
7	^{102}Ru	31.55%	Stable with 58 neutrons
8	^{103}Ru	Synthetic	39.26 days
9	^{104}Ru	18.62%	Stable with 60 neutrons
10	^{106}Ru	Synthetic	373.59 days

Table 2. Physical properties of platinum group elements.

5. Physical and chemical properties of Ru

Ruthenium (Ru), Rhodium (Rh), Palladium (Pd), Osmium (Os), Iridium (Ir) and Platinum (Pt) form the Platinum group metals. Some of the fundamental properties of platinum group metals are summarized in **Table 3** [8]. Ruthenium is silvery whitish, lustrous hard metal with a shiny surface. At room temperature, Ru does not lose its luster because it is unreactive in that condition but shows paramagnetic behavior [7]. At the higher temperature of around 800°C, Ru reacts with oxygen and gets oxidized [11]. It also reacts with halogens at higher temperature. As far as dissolution is concerned, Ruthenium does not dissolve in most of the acid or mixture of acids such as aqua regia which is a mixture of hydrochloric acid and nitric acid [7, 10]. When it is reacted with alkali it forms ruthenate ion which leads to dissolution of Ruthenium in alkalies (Eq. 1) [6].

	Ru	**Rh**	**Pd**	**Os**	**Ir**	**Pt**
Atomic number	44	45	46	76	77	78
Atomic weight	101.07 u ± 0.02 u	102.9055 u ± 0.00002 u	106.42 u ± 0.01 u	190.23 u ± 0.03 u	192.217 u ± 0.003 u	195.084 u
Electronic configuration	Kr 4d7 5 s1	Kr 4d8 5 s1	Kr 4d10	Xe 4f14 5d6 6 s2	Xe 4f14 5d7 6 s2	Xe 4f14 5d9 6 s1
Density(g/cc)	12.2	12.41	11.9	22.59	22.56	21.45
Melting point(°C)	2334	1963	1555	3033	2447	1768
Boiling point(°C)	4150	3697	2963	5027	4130	3825
Electronegativity	2.2	2.28	2.2	2.2	2.2	2.28

Table 3. Characteristics of main isotopes of ruthenium.

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$$\mathbf{[Ru]} \xrightarrow{\textbf{Alkali}} [RuO_4^{2-}] \text{ ---------------} \qquad (1)$$

Ruthenium **Ruthenate ion**

6. Chemical reactivity of ruthenium

6.1. Oxidation reaction of ruthenium

As noted above, Ruthenium undergoes oxidation reaction to form Ruthenium oxide [11]. When Ruthenium oxide undergoes further oxidation in the presence of sodium metaperiodate, Ruthenium tetraoxide (RuO_4) is formed (Eq. 2), with properties somewhat similar to those of OsO_4, in that both are strong oxidizing agents. However, RuO_4 differs from OsO_4 since it can easily oxidize diluted form of hydrochloric acid as well as ethanol at normal room temperature [12]. At temperatures above 100°C, RuO_4 get reduced to its dioxide. RuO_4 also has specific stain property which is utilized in electron microscopy to investigate organic polymer samples [11, 13].

$$\mathbf{[Ru]} \longrightarrow [RuO_2] \xrightarrow{[NaIO_4]} [RuO_4] \qquad (2)$$

Ruthenium Ruthenium Oxide **Ruthenium Tetraoxide**

At lower oxidation states such as +2 or +3, Ru does not undergo oxidation reaction. Ruthenium reacts with hydroxide ions to attain higher coordination number [13]. Ruthenium does not form oxoanion readily as seen with iron. Ruthenium attains +7 oxidation states when it reacts with cold and diluted potassium hydroxide to form potassium perruthenate [14]. Ruthenium can also attain same oxidation state when potassium ruthenate gets oxidize in the presence of chlorine gas [9].

6.2. Coordination complexes of ruthenium

Coordination complex is the process where a center molecule makes bond with surrounding atoms or ions which are also known as ligands. Ruthenium readily forms coordinate complexes with different derivatives. It reacts with pentaamines to form different coordination complex. Ruthenium reacts with pyridine derivatives to form tris (bipyridine) ruthenium (II) chloride (Eq. 3) [15]. Ruthenium also reacts with carbon containing compounds. Ruthenium forms Roper's complex when trichloride form of Ruthenium reacts with carbon monoxide [10, 15]. Ruthenium makes hydride complex when Ruthenium trichloride is heated in presence of alcohol which then reacts with triphenylphosphine to form chlorohydridotris (triphenylphosphine) ruthenium (II) (Eq. 4) [10].

$$\mathbf{[Ru] + C_5H_5N \longrightarrow C_{30}H_{24}N_6Cl_2Ru.6H_2O} \text{ --------} \qquad (3)$$

Ruthenium Pyridine tris (bipyridine) ruthenium (II) chloride

$$RuCl_3.XH_2O + C_{18}H_{15}P \xrightarrow{\text{Heat, Alcohol}} C_{54}H_{45}Cl_2P_3Ru \text{ ----------}$$

Ruthenium Trichloride **Triphenylphosphine** **Chlorohydridotris(triphenylphosphine)Ru(II)**

(4)

6.3. Catalytic activity of ruthenium

Ruthenium acts as a catalyst in many reactions. In the olefin metathesis, the carbene and alkylidene complex of Ruthenium act as a catalyst. In Fischer Tropsch reaction (Eq. 5), Ruthenium also acts as a catalyst [16]. Fischer Tropsch reaction is a reaction in which liquid hydrocarbons are formed as a product of reaction between hydrogen and carbon monoxide. Decomposition process of ammonia also employs Ru as catalyst [17]. Ru also catalyzes group of reactions called "borrowing hydrogen reactions". Borrowing hydrogen reaction is a reaction where two atoms of hydrogen are transferred to the catalyst to covert alcohol to carbonyl. The same reaction occurs in the conversion of alcohol to alkenes [5, 17].

Ruthenium carbonyl complex catalyzes the conversion of primary alcohol to aldehydes and secondary alcohol to aldehydes and ketones in the presence of a co-oxidant N-methylmorpholine-N-oxide (NMO) [8]. Ruthenium acts as a unique catalyst in oxidation reaction because of its varying oxidation state that ranges from −2 to +8 [6].

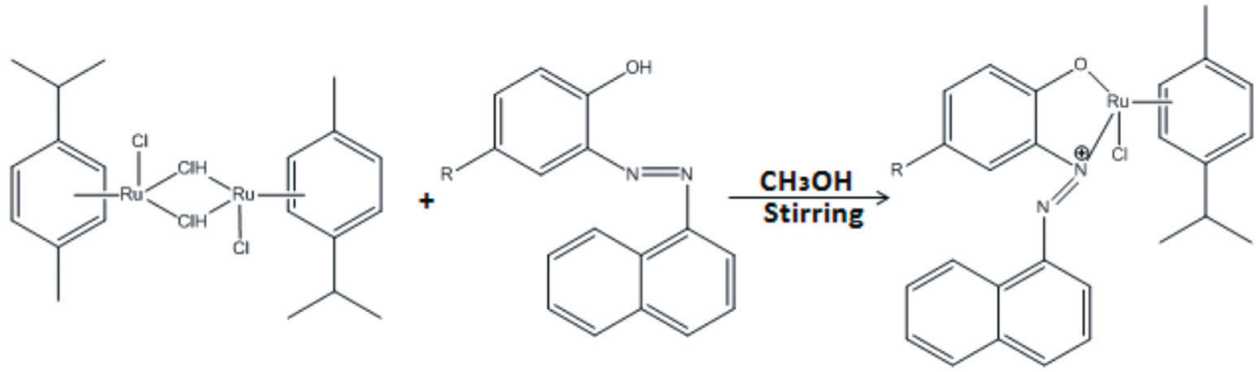
$$(2n + 1)\, H_2 + n\, CO \xrightarrow{\text{Ru(Catalyst)}} C_nH_{2n+2} + n\, H_2O \tag{5}$$

7. Ruthenium complexes

In recent years, there has been remarkable growth and evaluation in the field of coordination and organometallic chemistry of Ru. Many publications have appeared recently on the formation of Ru-based complexes and their applications in such areas as medicine, catalysis, biology, nanoscience, redox and photoactive materials. These developments can be related to the fact that Ru has the unique ability to exist in multiple oxidation states. Examples of these complexes and various applications of Ru are reviewed in the following sections.

7.1. Development of half-sandwich para-cymene ruthenium (II) naphthylazophenolato complexes

Ruthenium (II)-arene complex has a structure of three-legged piano stool with a metal at the center in a quasi-octahedral geometry which is occupied by byan arene complex. 2-(naphthylazo)phenolate ligands reacts with chloro-bridged (g6-p-cymene) ruthenium complex [{(g6-pcymene)RuCl}2(l-Cl)2] in methanol having molar ratio 1:1 at room temperature leads to formation of monomeric ruthenium(II) complexes. The formed complexes (**Figure 2**)



(R = Cl : L1(1) ; CH_3 : L2(2) ; OCH_3 : L3(3) ; OC_2H_5 : L4(4) ; NO_2 : L5(5))

Figure 2. Structure of (p-cymene) ruthenium (II) 2-(naphthylazo)phenolate complexes.

show the solubility in polar solvents (dichloromethane and acetone) and are insoluble in non-polar solvents (aspentane and hexane). It is stable in air and shows diamagnetic nature with the +2 oxidation state [6, 10].

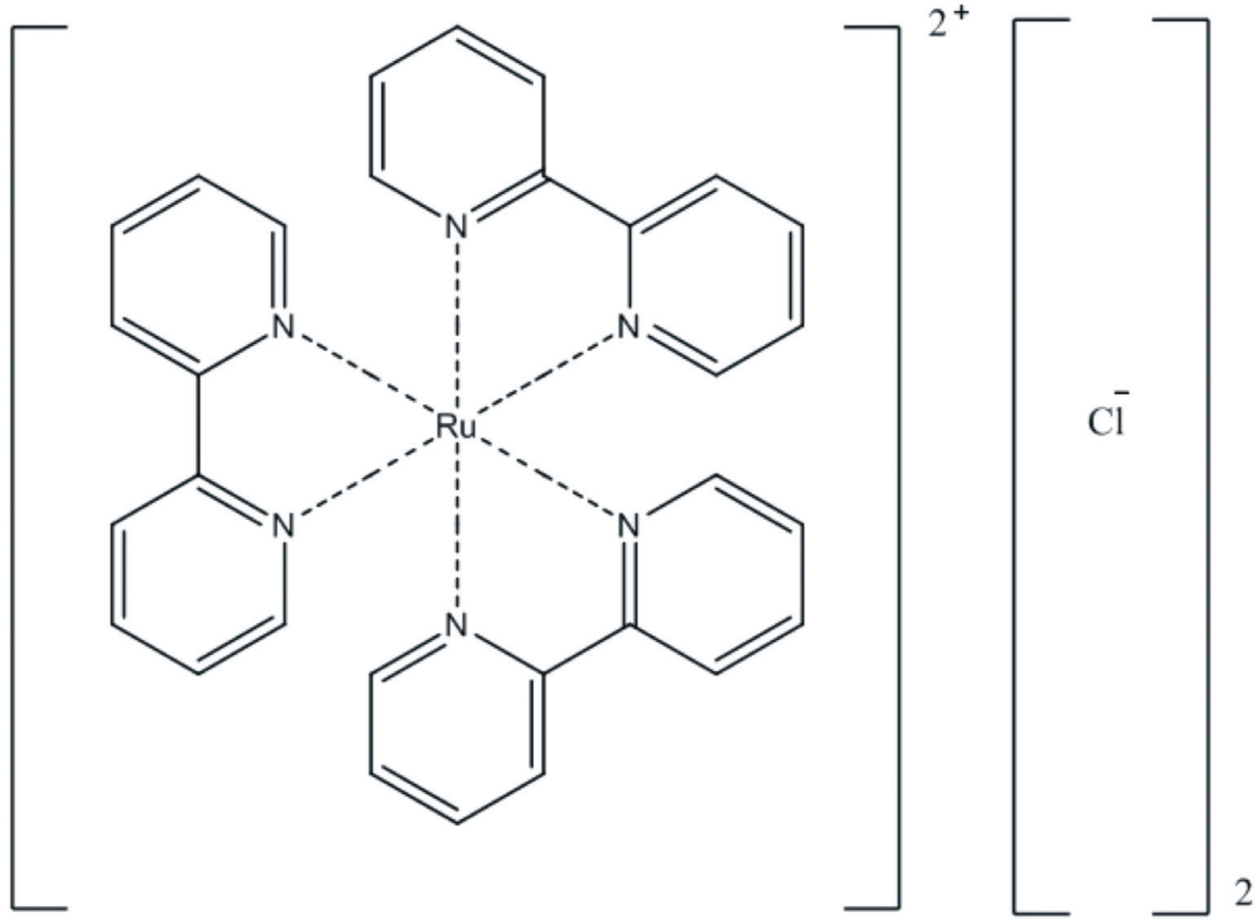


Figure 3. Structure of Tris (bipyridine) ruthenium (II) chloride.

7.2. Development of functionalized polypyridine ligands for ruthenium complexes

Polypyridine are coordination complexes containing polypyridine ligands such as 2,2′-bipyridine, 1,10-phenanthroline and 2,2′,6′2″-terpyridine. Polypyridines are multi-denated ligands which are responsible for characteristics property of metal complex they formed. Some of complexes show the characteristics of absorption of light by a process called metal-to-ligands charge transfer (MLCT). This said property of metal complex is due to the change in substituent to the polypyridine moiety. Among the polypyridine ligands for ruthenium complexes the mostly studied complex is Tris (bipyridine) ruthenium (II) chloride (**Figure 3**). It is a red crystalline salt having a hexahydrate form. Tris (bipyridine) ruthenium (II) chloride salt is prepared when aqueous solution of ruthenium trichloride reacts with 2,2′-bipyridine in the presence of reducing agent hypo-phosphorus acid. In this reaction Ru(III) gets reduced to Ru(II) [18].

8. Applications of ruthenium

Ruthenium has a wide variety of application in diverse fields. Few of the applications of Ruthenium are listed below.

8.1. General applications

Ruthenium finds application both in electronic industry and chemical industry. In electrical industry it is used in manufacturing of electronic chips [19]. Chemically it is used in the form of anodes for chlorine production in electrochemical cells [20]. Ruthenium is used as a hardener when it is mixed with other metals to form alloy. This characteristic of ruthenium is used in the preparation of jewelry of palladium [18, 20]. When Ruthenium forms alloy with titanium it improves its corrosion resistant property. Ruthenium alloys also find application in manufacturing of turbines of jet engines [17]. Fountain pen nibs also contain Ru tips. Ruthenium has also application in therapy. For instance 106 isotope of Ru has application in radiotherapy of malignant cells of eye [11]. RuO_4 is used in criminal investigations as it reacts with any fat or fatty substance having sebaceous pigments to give black or brown coloration due to formation of ruthenium dioxide pigments [12].

Ruthenium complexes tend to absorb light rays of visible spectrum. This property of ruthenium finds application in manufacturing solar cells for production of solar energy. [16] Ruthenium vapor get deposited on the surface of substrate and has magneto-resistive property. This property of Ru is used in making a layer or film on hard disk drives [12].

8.2. Biomedical applications

8.2.1. Applications in diagnosis

- Ruthenium is used for determination of calcitonin level in blood. This determination is helpful in diagnosis and treatment of diseases related to thyroid and parathyroid

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glands. In treatment of medullary thyroid carcinoma (MTC), determination of calcitonin level plays an important role. The process of determination of calcitonin level involves one step sandwich assay method. This method is carried out in two incubation steps. Each incubation process takes 9 min each. In first incubation, 50 microliters of sample of biotinylated monoclonal human calcitonin specific antibody and monoclonal human calcitonin specific antibody labeled with ruthenium complex are incubated. This incubation leads to formation of sandwich like complex where human calcitonin is carrying both biotinylated and ruthenylated complex. After the first step, second incubation step is done where streptavidin-coated microparticles is added. Streptavidin-coated microparticle makes complex with biotin. After the incubation step, measurement is done. For measurement, the mixture of incubation is aspirated into measuring cells and micro particles of mixture are magnetically attracted to the surface of electrode. After that the unbound particles are removed. Voltage is applied on to the electrode and induction of chemi-lumiscent emission is done and after that the response is studied with photomultiplier [12].

- Folate is the main constituent of synthesis of DNA. It is also essential for formation of red blood cells. Deficiency of folate leads to megalobalstic anemia. Deficiency of folate is estimated by determination of folate level in erythrocytes as well as serum. Ruthenium plays an important role in Elecys folate RBC assay in estimating folate deficiency in RBC. The process involved in folate determination is competition principle. This process involves three steps incubation method. In first incubation step folate pretreatment reagent is added which leads to release of folate from its binding sites (erythrocytes). In the second incubation step, Ru-labeled folate binding protein is added which makes complex with the sample. In the third incubation step streptavidin bounded microparticles are added which get attached to unbound sites of ruthenium-labeled folate binding protein. The whole complex is bound to solid phase via streptavidin and biotin. For measurement, the mixture of incubation is aspirated into measuring cells and microparticles of mixture are magnetically attracted to the surface of electrode. After that the unbound particles are removed. Voltage is applied on to the electrode and induction of chemi-lumiscent emission is done and after that the response is studied with photomultiplier [12].
- Ruthenium is also employed in detection of cyclosporine by Elecsys cyclosporine assay. Determination of cyclosporine is an important aspect for management of liver, kidney, heart lungs and bone marrow transplant patients receiving cyclosporine therapy [12].

8.2.2. Applications in treatment

History of medical science shows metals like gold has always been used for medicinal purpose. Though it is known that metals may have beneficial effect for health, but the exact mode of activity remains unknown. Ruthenium also has been applied in treatment [21].

- **Immunosuppressant:** Immunosuppressant is drug used to suppress hyperactivity of body's immune system. An immunosuppressant Cyclosporin A which has wide application in treatment of disease like anemia and psoriasis eczema has shown side effects such as nausea, renal diseases, and hypertension. To modify the action of Cyclosporin A, complex is made with Ru(III). Ruthenium cyclosporin complex gives a stable compound which results in an inhibitory effect on T lymphocyte proliferation [22].

- **Antimicrobial action:** antimicrobial drugs are drugs that inhibit microbial growth in human body. Ruthenium complex has its effectiveness against wide range of parasitic diseases. Microbial strains which are exposed to a certain kind of antimicrobial therapy become resistant to that drug. The resistance develops because the microbes mutate themselves against the organic compound of the drug. But with the formation of complex with certain metals the effectiveness of the drug increases as the microbes are unable to deal with the metal part of the organometallic complex of drug. In case of Chloroquine, Plasmodium species develops résistance against it, whereas when Chloroquine is complexed with ruthenium, resistance does not develop [23].

- **Antibiotic action:** antibiotics are drugs which are made from one particular microorganism and act on the other microorganism. Synthetic antibiotics are also nowadays made in laboratory. Antibiotic exhibit their action by entering the cell of microbes and targeting any vital biosynthetic pathway. Ruthenium has upper edge if it gets complexes with synthetic antibiotics. Ruthenium being a metal has better tendency to bind to the cellular component similar to Iron. When an organic moiety gets bind to a metal ion, at that time sharing or delocalization of cations between the two moieties occurs. The change in charges among the component of drug increases the permeability of cellular component in favor of drug. For example, Thiosemicarbazone shows a remarkable increase in its activity due to formation of complex of Ru [24].

- **Inhibitory effect on nitric oxides:** nitric oxide is a cellular component which is produced by many cells. The main physiological role of nitric oxide is to produce vasodilation. Nitric oxide does this action my increasing cellular level of cyclic-guanosine 3′,5′-monophosphate (CGMP) which is a secondary messenger in the physiological system. Over production of nitric acid can cause many disorders associated with respiratory system such as tumor of respiratory system. It also causes severe hypotension on over production. It also causes gastric inflammatory disorders. Ruthenium has beneficial effect in treatment of over production of nitric oxides. When ruthenium is administered in complex form such as ruthenium poly amino carboxylates, excess nitric oxide present in blood binds to this complex readily and reduces ruthenium to form an unabsorbable complex there by inhibiting its unwanted effects [25].

8.2.3. Applications of Ruthenium in cancer research

- **Anti-carcinogenic activity:** cancer or carcinoma is a stage where body cells undergo uncontrolled proliferation and having invasiveness and metastatic property. To treat carcinoma, drug therapy aims at inhibiting synthesis of cancerous protein as well as inhibiting DNA replication. In market there are drugs such as Cisplatin which uses platinum as anticancer agent. Though platinum has shown better results in treatment of cancer but in some cancers, platinum is unable to show positive results. This shortcoming of Platinum made way for use of Ruthenium as a new entrant in treatment of cancer. Ruthenium shows the ability to bind to the DNA and inhibits its replication as well as protein synthesis. Ruthenium has low aqueous solubility which was the only drawback of it. This drawback was countered by using dialkyl sulfoxide derivative of ruthenium. The mechanism of action of ruthenium as an anticancer agent is that it causes apoptosis of tumor cells by acting at DNA level. Apoptosis is a controlled destruction of cells [17, 18].

- **Radiation therapy:** in cancer treatment radiotherapy has also been used. Radiation therapy becomes beneficial only when it is proximal to the cancerous cell. The agents used in radiation therapy are called radio sensitizers. To increase the proximity to cancerous cells radio sensitizers' complexes with ruthenium are used as Ru has the affinity to bind to DNA easily [18, 19].

- **Photodynamic therapy:** it is a therapy where chemicals and electromagnetic radiations are used. In this therapy chemicals are targeted on the cancerous cell, these chemicals become cytotoxic when they interact with electromagnetic radiation. In this therapy Ruthenium find its application as it increases the access of these chemicals to the cancerous cells [20, 21].

- **Action on cancerous mitochondria:** mitochondria are the power house of any cell. This makes it a potential target for anticancer therapy. Ruthenium red is a type of ruthenium which is used to stain mitochondria. Mitochondrial surface has some calcium entity on it. When ruthenium red is added, it reacts with this calcium and stains the mitochondria. Ruthenium red also has tumor inhibiting activity. However, ruthenium red is not preferably used clinically as it has major side effects [20, 22].

- **Effect on metastasis:** metastasis is the ability of cancerous cell to spread in the body by lymphatic or circulatory system. A tumor cell more than 1 mm in size requires additional blood supply to spread in the body. Formations of new blood vessels are called angiogenesis. Drugs which act as anti-metastasis many inhibit this action. Ruthenium complexes anti-metastatsis drug namely NAMI-A does the same action by binding to the mRNA and production of denatured protein which gets accumulated on the surface of tumor making a hard film and prevents any blood supply to the tumor cell. This action inhibits the metastasis. Ruthenium has additional benefit that it easily crosses any cell so the reach of the drug increases [23, 26].

9. Summary and conclusions

Ruthenium with atomic number of 44 and symbol Ru was discovered by Russian chemist Karl Klaus (1796–1864). In earth's crust, it is quite rare, found in parts per billion quantities, in ores containing some of the other platinum group metals. It is silvery whitish, lustrous hard metal with a shiny surface. The ability of Ru to exist in many oxidation states is an important property of this rare element which plays an important part in its applications. Ruthenium readily forms coordinate complexes and these complexes have their applications in diverse fields such as medicine, catalysis, biology, nanoscience, redox and photoactive materials. In biomedical fields Ru is used for diagnosis and treatment purpose. For example, Ru is used for determination of calcitonin level in blood which is helpful in diagnosis and treatment of diseases related to thyroid and parathyroid glands. Also, Ru plays an important role in Elecys folate RBC assay in estimating folate deficiency in RBC. Ruthenium cyclosporin complex gives a stable compound which results in an inhibitory effect on T lymphocyte proliferation which shows its immune-suppressant action. Ruthenium complex has its effectiveness against wide range of parasitic diseases. Ruthenium shows the ability to bind to the DNA and inhibits its replication as well as protein synthesis. This property helps in the treatment of cancer. This chapter gives a brief account of the various properties of Ru which are exploited for applications in the medical field. It is likely that in the coming years, further research will lead to even more useful applications of this miraculous element.

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