^{14}C ratio during different geological time and made a calibration curve which useful to estimate the calendar age of a given sample.

With the advancement of mass spectrometry, the amount of ^{14}C was directly measured using accelerated mass spectrometry (AMS) instead of measuring the number of beta particles emitted. The advantages of this method are required sample size is smaller and quicker analysis.

Who invented the of theory radiocarbon dating?

Willard Libby is the founder of radiocarbon dating. He won the Noble Prize in Chemistry for this invention in 1960.

What are the applications and findings obtained using this theory?

There are many forensic and archeological applications of radiocarbon dating while some of the results revealed many facts in history. One famous incident was the radiocarbon dating measurement taken to examine the authenticity of Shroud of Turin, a linen cloth associated with burial of Jesus where the results showed it was a much later product than the time of Jesus.

Is the radiocarbon dating applicable for any aged fossils like dinosaurs?

Remember that the half life of ^{14}C is 5730 years. As a rule of thumb, radioactivity cannot be measured after 10 half lives have elapsed, because at that time the number of radioactive atoms will be too low. Therefore, radiocarbon dating is applicable only the age of the sample is less than 60 000 years old.

How reliable is the radiocarbon dating in age determination?

One needs to keep in mind that the radiocarbon tells you the time elapsed from death to present. It will not provide any information of the life time of the organism. Therefore, estimation of an age of a tree with several hundred years old can give erroneous results.

In addition there are many other facts that contribute to error in radiocarbon measurements due to change in $^{14}C/^{12}C$ ratio. Some of the reasons are as follows.

- Natural disasters such as volcano eruptions, and other major natural disasters.
- Human activities such as coal and oil burning, nuclear testing and weakening of ozone due to green house effects may decrease 14C/12C ratio.
- Contamination of carbon from a different geological age to the given sample can give erroneous results in radiocarbon dating.

~~~*~~~

IUPAC Nomenclature of Coordination Compounds

Dr. Mahesh C. Karunarathne

Senior Lecturer, Department of Chemistry, University of Sri Jayewardenepura, Nugegoda

Systematic naming of chemical compounds is of utmost importance due to the fact that nonsystematic trivial names, common names, industrial trade names, and other names create chaos within the scientific community. A broadly accepted system of naming chemical compounds must resolve any ambiguities which might arise and should clarify any confusion over the way in which nomenclature should be used. Furthermore, the naming system must provide a comprehensive set of guidelines to name all known and any new compounds and it should be as simple as possible in order to assist all levels of scientists.

Chapter IR-9 of the 2005 revised Red Book; "Nomenclature of Inorganic Chemistry, IUPAC Recommendations 2005," published for the International Union of Pure and Applied Chemistry (IUPAC) by The Royal Society of Chemistry provides a complete set of guidelines for the naming of coordination compounds. The scope of this article is only to provide an introductory set of instructions sufficient within the undergraduate context of coordination chemistry. Furthermore, it is important to note that the IUPAC recommendations provided for coordination compounds overlap to a great extent with systematic naming of both inorganic and organic compounds.

Werner-type coordination compounds, where the coordination entity comprised of a central metal atom (or atoms) surrounded by ligands are named using additive nomenclature. The name identifies the central metal atom, its oxidation state, the ligands that are attached
~~~

to it, and the overall charge on the structure. Cation is named before anion for ionic compounds regardless of the fact that they are coordination entities or not.

Eg.1: a. $[Ni(OH_2)_6]Cl_2$ hexaaquanickel(II) chloride
b. $K_4[Fe(CN)_6]$ potassium hexacyanidoferrate(II)

The coordination complex is given in square brackets in formula writing as shown in Eg. 1 and the name of this coordination entity is constructed by following a set of nomenclature rules.

1. Identify the central atom(s) and identify the ligands attached to each metal atom.
2. Ligands are named first and organized in alphabetical order along with any appropriate multiplier prefixes (or number prefixes). The prefixes do not affect the order of the ligand lineup.

E.g. 2: a. $[CoCl(NH_3)_5]^{2+}$
pentaamminechloridocobalt(III)
b. $[Al(OH)_2(OH_2)_4]^+$
tetraaquadihydroxidoaluminium(III)

An anion name ending in 'ide', 'ite' or 'ate' suffix, the final 'e' is replaced by 'o', giving 'ido', 'ito' and 'ato', respectively, for the corresponding ligand name. Organic ligands binding to metals through carbon atoms are assigned alternative names that originated from substituent group nomenclature of organic chemistry ending in 'yl' suffix replacing 'ane' suffix of the parent organic molecule name. Names of neutral and cationic ligands, including organic ligands, are used without modification. Common anionic and neutral ligand names are listed alphabetically in table 1 and 2, respectively.

Table 1: Names of anionic ligands.

Name	Formula
acetato	CH_3COO^-
acetylacetonato	$CH_3COCHCOCH_3^-$
amido	NH_2^-
azido	N_3^-
benzenido	$C_6H_5^-$
bromido	Br^-
carbonato	CO_3^{2-}
chlorido	Cl^-
cyanido	CN^-
cyclopentadienido / cyclopentadienyl	$C_5H_5^-$
ethanido / ethyl	$C_2H_5^-$
fluorido	F^-
hydrido	H^-
hydroxido	OH^-
iodido	I^-
methanido / methyl	CH_3^-
nitrato	NO_3^-
nitrido	N^{3-}
nitrito-κN	NO_2^-
nitrito-κO	ONO^-
oxido	O^{2-}
oxalato	$C_2O_4^{2-}$
peroxido	O_2^{2-}
phenyl	$C_6H_5^-$
sulfanido	HS^-
sulfido	S^{2-}
thiocyanato-κN	NCS^-
thiocyanato-κS	SCN^-

Table 2: Names of neutral ligands.

Name	Formula
ammine	NH_3
aqua	H_2O
carbonyl	CO
dinitrogen	N_2
dioxygen	O_2
ethylenediamine	$NH_2CH_2CH_2NH_2$
pyridine	C_5H_5N
tetrahydrofuran	C_4H_8O
trimethylphosphane	$P(CH_3)_3$
triphenylphosphane	$P(C_6H_5)_3$

Enclosing marks are required for ligands containing multiplicative prefixes such as (triphenylphosphane), for names of substituted organic ligands such as (methylamine), and wherever necessary to avoid ambiguity. Prefixes di, tri, tetra, etc are generally used with the names of simple ligands and enclosing marks are not required (see E.g 1 and 2). However, the prefixes bis, tris, tetrakis, pentakis, or hexakis are used with complex ligand names and enclosing marks must be placed in order to avoid ambiguity. You would realize the importance of this rule by naming $(NH_3)_2$ as diammine, but $(NH_2Me)_2$ as bis(methylamine), to distinguish it from $(NHMe_2)$, dimethylamine.

Eg. 3: a. $[Co(NH_3)_4(NMe_2)_2]^+$
tetraamminebis(dimethylamido)cobalt(III)
b. $[Ir(CO)_2H(PPh_3)_2]$
dicarbonylhydridobis(triphenylphosphane)iridium(I)

3. Central metal atom or ion is named last followed by the oxidation state of the central metal ion given in Roman numeral in parenthesis (see E.g 1, 2 and 3). Arabic number zero is used to indicate the zero oxidation state of the metal. Alternatively, in a case where the oxidation state of the central metal cannot be defined without ambiguity, the charge on a coordination entity may be indicated. In such cases the net charge is written in Arabic numbers followed by the charge sign, and enclosed in parentheses.

E.g. 4: a. $[Ni(CO)_3(py)]$
tricarbonylpyridinenickel(0)
b. $[CoCl(NH_3)_5]^{2+}$
pentaamminechloridocobalt(2+)
[see alternative name in E.g. 2a]
c. $K_4[Fe(CN)_6]$
potassium hexacyanidoferrate(4-)
[see alternative name in E.g. 1b]

4. No spaces are left between parts of the name that refer to the same coordination entity. In order to indicate anionic coordination entities, the ending 'ate' is added to the central metal atom name.

E.g. 5: a. $K_2[OsCl_5N]$
potassium pentachloridonitridoosmate(2-)
b. $[Pt(py)_4]^{2+}[Pt(Cl)_4]^{2-}$
tetrapyridineplatinum(II) tetrachloridoplatinate(II)

For some of the transition metal and main-group metal centers, the name ending with 'ate' is different from the name of the metal used in cationic or neutral complexes and are listed in table 3.

Table 3: Names of some metal atoms.

Metal atom	Name (neutral or cationic)	Name (anionic)
Mn	manganese	manganate
Fe	iron	ferrate
Cu	copper	cuprate
Pb	lead	plumbate
Au	gold	aurate
Ag	silver	argentate
Sn	tin	stannate

5. Ambidentate ligands possess more than one different potential donor atoms. The donor atom of such ligands is indicated by the element symbol of the donor atom preceded by a Greek small letter kappa, κ (see Table 1).

E.g. 6: a. $[Co(NH_3)_5(NO_2)]^{2+}$
pentaamminenitrito-κN-cobalt(III)
b. $[Co(NH_3)_5(ONO)]^{2+}$
pentaamminenitrito-κO-cobalt(III)

6. A ligand bridging two metal centers is indicated by adding Greek small letter mu, μ before the ligand name and separated from it by a hyphen. Multiplicative prefixes are used to indicate more than one bridging ligands of the same kind.

E.g. 7: a. $[\{Cr(NH_3)_5\}_2(\mu\text{-}OH)]^{5+}$
μ-hydroxido-bis(pentaamminechromium)(5+)
b. $[\{Ru(NH_3)_4\}_2(\mu\text{-}NH_2)_2]^{4+}$
di-μ-amido-bis[tetraammineruthenium(III)]
c. $[\{Co(en)_2\}_2(\mu\text{-}NH_2)(\mu\text{-}OH)]^{4+}$
μ-amido-μ-hydroxido-bis[bis(ethylenediamine) cobalt(III)]

If the above information and guidelines are insufficient to name a coordination compound without ambiguity, one may refer the IUPAC revised red book of 2005. It provides additional fine details associated with the rules listed above as well as further rules of complete coordination compound nomenclature.