CHEM1102 Worksheet 13: Coordination Chemistry and Introduction to Kinetics

Model 1: Naming Coordination Compounds

The name of a coordination compound consists of two parts: the complex ion and the counter ions:

- The cation is named *before* the anion.
- The *number* of counter ions is not specified, as it can be inferred from the charge of the complex.
- There is a *space* between the names of the cation and anion so we can tell which is which.

The name of the complex ion is written as *one word*, with *no space* between its parts. To name the complex ion, follow steps 1-6:

1. Neutral ligands use the name of neutral molecule. For example, the molecule $NH_2CH_2CH_2NH_2$ is ethylenediamine and this is also used when it is a ligand. There are three common exceptions to this rule:
   - H_2O – aqua
   - NH_3 - ammine (*note the double m to distinguish it from RNH_2 amine ligands*)
   - CO - carbonyl
2. Negatively charged ligands use the name of the anion with the last letter changed to 'o'. Examples include:

anion name	name when coordinated	anion name	name when coordinated
fluoride	fluorido	hydroxide	hydroxido
chloride	chlorido	iodide	iodido
bromide	bromido	nitrate	nitrato
oxide	oxido	sulfide	sulfido

3. The ligands are named first, in alphabetical order according to the name of the *ligand*.
4. Numerical prefixes based on the Greek, di-, tri-, tetra-, penta-, hexa- are used to indicate the presence of more than one of any given ligand. These prefixes are *disregarded* for the purpose of determining the order of listing ligands in the name. Double vowels such as in "hexaaqua" and "pentaammine" are retained.
5. The name of the complex ion is completed with that of of the metal ion. The name of the metal ion includes its oxidation number and this is given by Roman numerals written in brackets. There is *no space* between *any* part of the name of the complex ion, including the metal atom and its oxidation number.
6. If the complex ion is *negatively* charged, the name of the metal ion is changed with 'ate' added to the name of the metal atom. When the metal name ends in 'um', the metal's name is first stripped to the second last consonant. The oxidation number is written after ‘ate’.
7. For historic reasons, some elements are given their Latin names (stripped to the second last consonant) when present in complex anions:

metal	metal name in an anionic complex	metal	metal name in an anionic complex
iron	ferrate	gold	aurate
copper	cuprate	lead	plumbate
tin	stannate	antimony	stibnate

Examples

A. $[Co(NH_3)_5(OH_2)]Cl_2$:

- The compound contains the complex ion $[Co(NH_3)_5(OH_2)]^{2+}$ and two Cl^- counter ions.
- The complex ion contains 5 ("penta") ammonia ligands ("ammine") and 1 water ligand ("aqua").
- Alphabetically, "ammine" is before "aqua".
- The oxidation number is +2 so the metal ion is cobalt(II) (with no space between the element and its oxidation number)
- Hence, the complex ion is pentaammineaquacobalt(II), This is written as one word with no spaces.
- Counter ions are not bonded to the complex ion and are written as a separate word. The complex ion is a cation and thus *precedes* the anion in the name. There is a space between cation and anion so they can be distinguished.
- The compound is **pentaammineaquacobalt(II) chloride.**

B. $Cs_2[CuCl_4]$:

- The compound contains the complex ion $[CuCl_4]^{2-}$ and two Cs^+ counter ions.
- The complex ion contains 4 ("tetra") Cl^- ligands ("chlorido").
- The complex ion is an anion so the ending "ate" is used. For copper, the "cuprate" is used.
- The oxidation number is +2 so the metal is cuprate(II).
- Hence, the complex ion is **tetrachloridocuprate(II)**. This is written as one word with no spaces.
- Counter ions are not bonded to the complex ion and are written as a separate word. The complex ion is a anion and thus the counter cation *precedes* the anion in the name. There is a space between cation and anion so they can be distinguished.
- The compound is **caesium tetrachloridocuprate(II).**

Critical thinking questions

1. Name the complex ions below.

   (a) $[CoCl(NH_3)_5]^{2+}$

   (b) $[AuCl_3(OH)]^-$

   (c) $[CrCl_2(OH_2)_4]^+$

   (d) $[Ru(NH_3)_5(OH_2)]^{3+}$

2. Name the coordination compounds below:

   (a) $[CoCl(NH_3)_5]Cl_2$

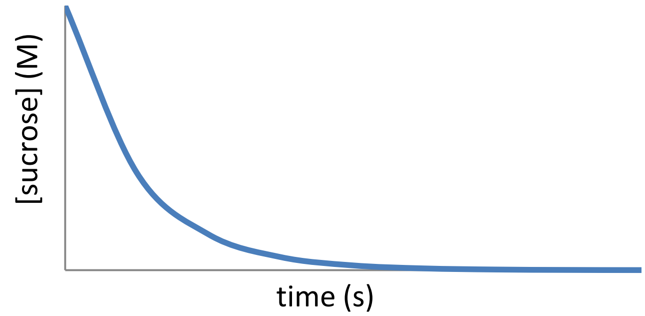
   (b) $K[AuCl_3(OH)]$

   (c) $[CrCl_2(OH_2)_4]Cl$

   (d) $[Ru(NH_3)_5(OH_2)]Br_3$

   (e) $[Ni(en)_3]I_2$ (en = ethylenediamine)

Model 2: Rate of Reaction



The figure opposite shows how the sucrose concentration changes when it reacts with acid according to the reaction below:

sucrose + H_3O^+ → fructose + glucose

The rate of the reaction can be measured by measuring the *change* in the concentration of sucrose, H_3O^+, fructose or glucose over *time*:

$$\text{rate} = -\frac{\Delta[\text{sucrose}]}{\Delta t} = -\frac{\Delta[\text{H}_3\text{O}^+]}{\Delta t} = +\frac{\Delta[\text{fructose}]}{\Delta t} = +\frac{\Delta[\text{glucose}]}{\Delta t}$$

Critical thinking questions

1. What are the units of rate?

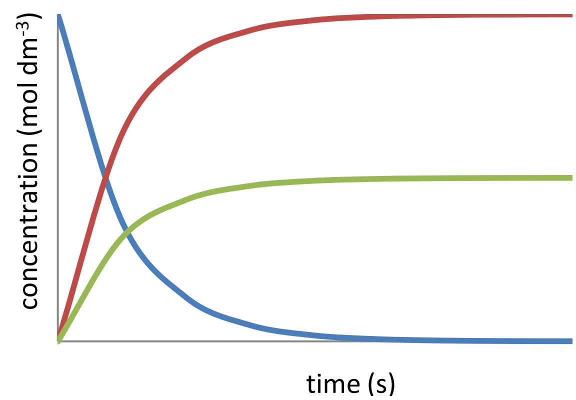
2. Sketch on the figure above how the concentration of *fructose* will be changing over the same time period.

3. Why is there a minus sign before Δ[sucrose]/Δt and Δ[H_3O^+]/Δt and a plus sign in front of Δ[fructose]/Δt and Δ[glucose]/Δt in the equation above for the rate?

4. The change in concentration with time of the reactants and products for the reaction below is shown in the figure opposite.

   $2NO_2(g)$ → $2NO(g) + O_2(g)$

   Label each curve with the chemical it represents.



Model 3: The Rate Law

The rate of reactions are often found to be proportional to the concentration of each *reactant* raised to some power:

$$\text{rate} \propto [\text{reactant}_i]^{x_i}$$

x_i is called the *order* of the reaction with respect to reactant$_i$ and is commonly an integer such as 0, 1 or 2. The order of the reaction is the sum of all x_i: order = $\sum_{i=1}^{n} x_i$

The relationship between the rate of a reaction and the concentration of the reactants is known as the rate law. For the hydrolysis of sucrose in Model 2, for example, it is found to be

rate ∝ [sucrose][H_3O^+] or rate = k [sucrose][H_3O^+]

k is the rate constant and is simply the proportionality constant.

Critical thinking questions

1. What happens to the rate of a reaction if the initial concentration of the reactant is doubled for each value of x below?

   (a) $x = 2$ (b) $x = 1$ (c) $x = 0$

2. For the hydrolysis of sucrose, what happens to the rate of the reaction for each of the changes to the initial concentrations of the reactants below?

(a) [sucrose] is doubled but [H_3O^+] is not changed.

(b) [sucrose] is not changed but [H_3O^+] is doubled.

(c) Both [sucrose] and [H_3O^+] are doubled.

3. Lactose can be decomposed into galactose and glucose through acid hydrolysis or using the enzyme lactase. In the basic environment of the intestine, only the enzyme catalysed decomposition is possible and lactose intolerance in humans arises from a deficiency of lactase. In the acidic environment of the stomach, however, hydrolysis should still occur and much research has been devoted to its study.

The table below shows the results from 3 experiments in which the initial rate of lactose decomposition was measured at different initial concentrations of lactose and acid.

experiment	initial rate (M s^{-1})	$[\text{lactose}]_0$ (M)	$[H_3O^+]_0$ (M)
(1)	0.00116	0.01	0.001
(2)	0.00232	0.02	0.001
(3)	0.00464	0.01	0.004

(a) Between experiments (1) and (2), how were $[\text{lactose}]_0$ and [H_3O^+] changed? What effect did this have on the rate?

(b) Between experiments (1) and (3), how were $[\text{lactose}]_0$ and [H_3O^+] changed? What effect did this have on the rate?

(c) Using your answers to Q1 and to parts (a) and (b), determine the values of x and y in the rate law.

$$\text{rate} = k[\text{lactose}]^x[H_3O^+]^y$$

(d) Between experiments (2) and (3), how were $[\text{lactose}]_0$ and [H_3O^+] changed and what effect did this have on the rate? Check that this is consistent with your rate law.

(e) Using your rate law and any one of the experiments, determine the value of the rate constant, k. Remember that a measurement is meaningless without a unit.