Note:

The following are the list of preparatory problem topics that have been revised.

Tasks: 14 (14.1), 19 (structure of Perovskite), 27 (NMR data), 29 (IR data added).

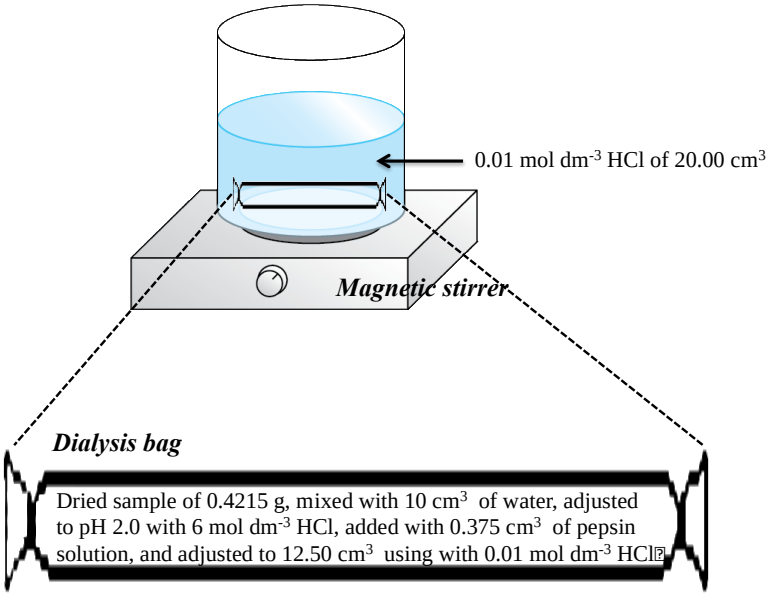
For clarity, the corrections are highlighted in yellow.

Task authors

Revised Preparatory Problems

Task 14. Spectrophotometric Determination of Iron

To study in vitro gastric digestion of iron, the following procedure is carried out. Dried and homogeneously ground supplement tablet of 0.4215 g is accurately weighed, mixed with 10 cm^3 of water, adjusted to pH 2.0 with 6 mol dm^{-3} HCl, 0.375 cm^3 of pepsin solution (16% w/v) added, and adjusted to 12.50 cm^3 with 0.01 mol dm^{-3} HCl. This mixture was quantitatively transferred into a dialysis bag of a fixed volume, which is further immersed for 2 hours in a 20.00 cm^3 solution containing 0.01 mol dm^{-3} HCl. Iron released by gastric digestion is dialyzed until the concentration of iron inside and outside the dialysis bag are equal.



To determine the gastric digestible iron from the supplement tablet, colorimetric measurement after complex formation between ferrous ion (M) and complexing agent (L) is carried out at pH 5.0. The resulting ML_3 complex exhibits light absorption at 520 nm, whereas M and L do not absorb light at this particular wavelength.

14.1) Under a certain condition that the complexed iron is in the form of ML_3, consider the absorbance values obtained from the total concentration of metal (C_M) and the total concentration of ligand (C_L) in the following table:

C_M, mol dm^{-3}	C_L, mol dm^{-3}	Abs (at 520 nm), pathlength (b) = 1 cm
6.25×10^{-5}	2.20×10^{-2}	0.750
3.25×10^{-5}	9.25×10^{-5}	0.360

In an excess of L, all of iron is in the form of ML_3.

a) Calculate the molar absorptivity (ε) of ML_3 complex

b) Calculate the formation constant (K_f) of ML_3 complex

14.2) The CHN analysis shows that the complexing agent (L) contains 80% C, 4.44% H, and 15.56% N. The molar mass of this compound is 180 g. Determine the molecular formula of L.

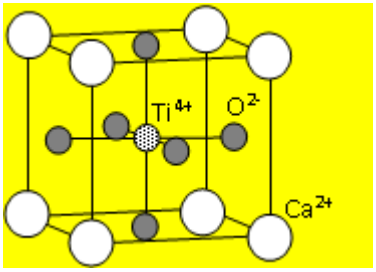
14.3) The Fe^{2+} complex, ML_3, adopts the octahedral structure (assume perfect octahedral geometry for each isomer of these three complexes). Sketch the d-orbital splitting diagram for ML_3. Draw all possible isomers of Fe^{2+} complex. Order the magnitudes of Δ_o (crystal field splitting) of these three complexes and explain.(Spectrochemical series: $I^- < Br^- < Cl^- \approx SCN^- < F^- \approx$ urea $< ONO^- \approx OH^- < H_2O < NCS^- <$ pyridine $\approx NH_3 <$ en $<$ bipy $<$ *o*-phen $< NO_2^- < CN^- \approx$ CO)

14.4) To determine the dialyzable iron concentration (iron outside the dialysis bag), 5.00 cm^3 of the solution outside the dialysis bag is added with a reducing agent to ensure that all of dissolved iron is in the ferrous ion form. Then, the solution is adjusted to the suitable pH, followed by addition of excess amount of complexing agent (L) and deionized water added to make up the volume to 50.00 cm^3 in a volumetric flask. The absorbance measured at 520 nm is 0.550. Calculate the concentration of dialyzable iron (in unit of mg dm^{-3}).

14.5) Presumable, all of iron in the supplement tablet is completely digestible in the gastric condition. Determine in mg the iron in 1.0000 g of supplement tablet.

Task 19. Perovskite Structure

A mineral perovskite crystallizes in the cubic unit cell in which Ca^{2+} and O^{2-} ions constitute a ccp arrangement and Ti^{4+} ion occupies an interstitial hole as shown here.



19.1) Based on the unit cell above, what is the empirical formula of perovskite?

19.2) Name types of interstitial holes present in the ccp unit cell. How many holes are there, for each type, within the unit cell?

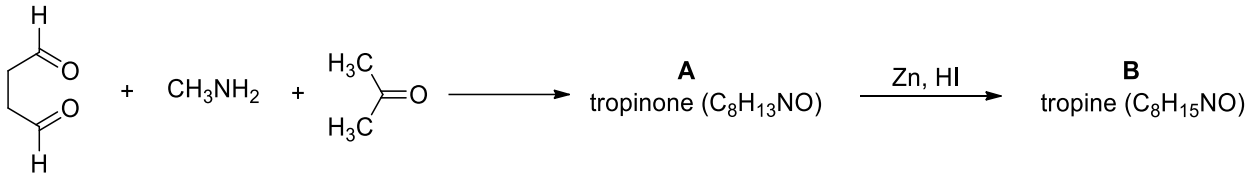
19.3) From your answer in 19.2, which type of interstitial hole is occupied by Ti^{4+} ion?

Task 27. Atropine

Atropine is an organic compound used to treat certain types of nerve agent and pesticide poisonings. This compound can be synthesized from tropine and tropic acid in one step.

27.1) Tropine can be prepared as shown in the diagram below. The first step of this synthesis is “double Mannich reaction” (Robinson, 1917).

Write down the structural formulae of compounds **A** and **B**.



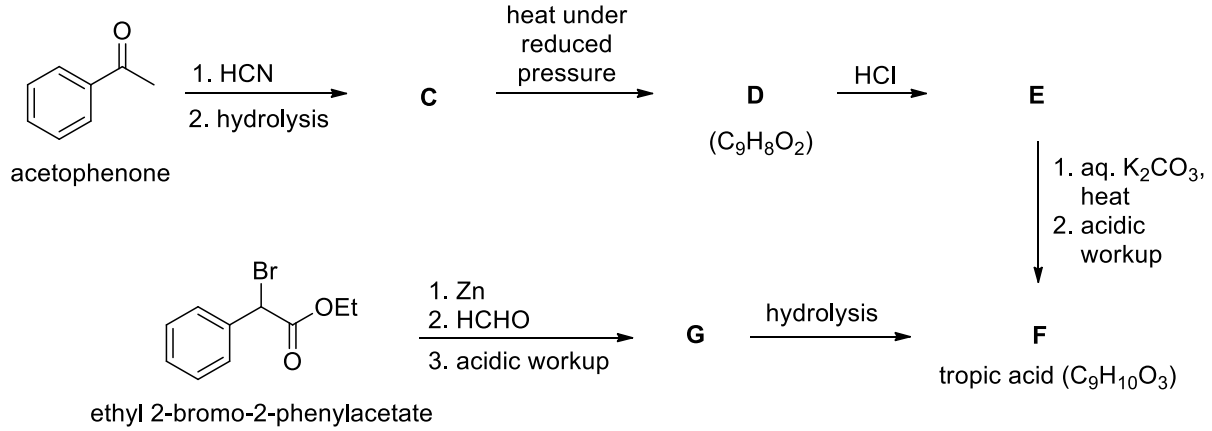
27.2) Tropic acid can be prepared from the reaction of acetophenone and HCN followed by hydrolysis, elimination, addition and nucleophilic substitution (Mackenzie and Ward, 1919). In this synthesis, it should be noted that the electrophilic addition by HCl did not follow Markovnikov's Rule, and the anti-Markovnikov product (**E**) was obtained.

Tropic acid (**F**) can also be prepared in only three steps from ethyl 2-bromo-2-phenylacetate and paraformaldehyde (Pernot, 1950). NMR data of tropic acid (**F**) are provided below.

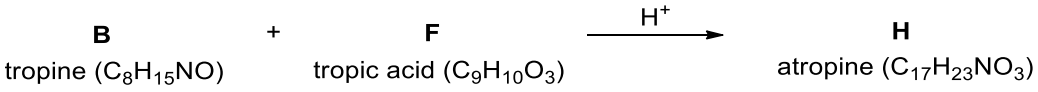
^{1}H NMR (400 MHz, d-DMSO): δ 12.35 (br, s, 1H), 7.34-7.25 (m, 5H), 4.91 (br s, 1H), 3.91 (dd, *J* = 10.0, 8.4 Hz, 1H), 3.64 (dd, *J* = 8.4, 6.0 Hz, 1H), 3.56 (dd, *J* = 10.0, 6.0 Hz, 1H).

^{13}C NMR (101 MHz, d-DMSO) δ 173.7, 137.1, 128.4, 128.0, 127.1, 63.4, 54.3

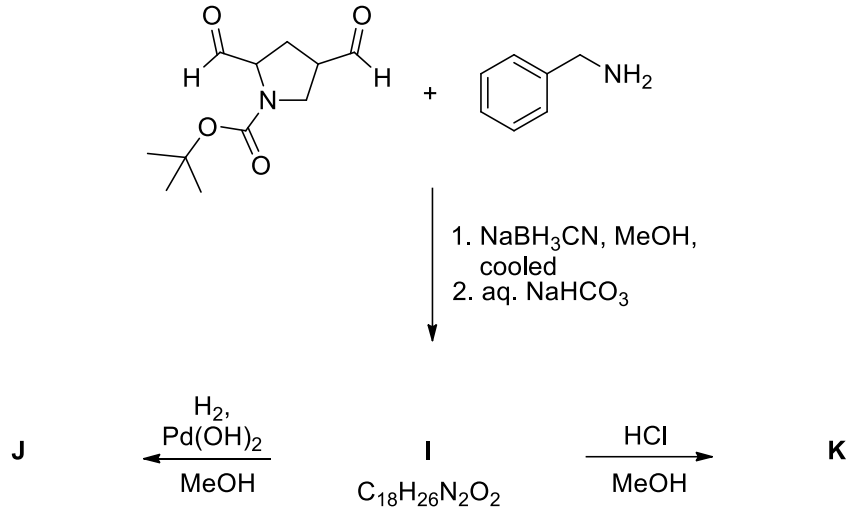
Write down the structural formulae of compounds **C**-**G** in the diagram below. t



27.3) When tropine was combined with tropic acid under acidic conditions, atropine was produced. Write down the structural formula of atropine.



27.4) Predict the major products of the reactions shown below. ^{13}C NMR spectrum of compound **I** shows nine signals in the range of 0-80 ppm, four signals in the range of 120-140 ppm, and one signal at 155 ppm. ^{13}C NMR spectrum of compound **J** shows eight signals in the range of 0-80 ppm and one signal at 155 ppm. ^{13}C NMR spectrum of compound **K** shows seven signals in the range of 0-80 ppm and four signals in the range of 120-140 ppm.



Task 29. Synthesis towards Anatoxin-a

Anatoxin-a (**I**) is a secondary amine alkaloid with acute neurotoxicity that can cause death by respiratory paralysis. This compound is produced by several different genera of cyanobacteria found all over the world. In 2004, Jehrod B. Brenneman and Stephen F. Martin reported a concise synthesis of anatoxin-a from commercially available D-methyl pyroglutamate, which was converted to compound **A**. Write down the structural formulae of compounds **B**, **C**, **F**, **H** and **I** in the boxes provided.