華中國際學校
Hwa Chong INTERNATIONAL SCHOOL
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2019 IB2 HL Chemistry Prelim Exam Paper 3 – *Answers*

Section A

1. Rhubarb, spinach and beet are example of plants with high oxalate–content foods. Oxalic acid, $H_2C_2O_4$ and its salts occur as end–products of metabolism in these plants. Consuming these plants may have some adverse effects in our bodies. The oxalate ion ($C_2O_4^{2-}$) binds with primarily calcium and can cause stone formation in the urinary tract.

However to reduce the oxalate content, soaking these plants in **hot water** may possibly reduce the oxalate content by action of leaching. The solution containing these ions can then be quantitatively determined. Methods like redox titration with potassium permanganate, $KMnO_4$, can be used to determine the amount of oxalate ion in plants. The redox reaction between oxalate and permanganate ion is shown as below:

$$2MnO_4^- + 16H^+ + 5C_2O_4^{2-} \rightarrow 2Mn^{2+} + 8H_2O + 10CO_2$$

(a) (i) Suggest a plausible research question for the above study mention. [1]

How does increasing in temperature/ change in temperature of the water affect the leaching/extracting/ removal of oxalate ions from spinach/ rhubarb/ beet via redox titration with standard solution of $KMnO_4$./
How does duration of soaking affect the leaching/extracting/ removal of oxalate ions from spinach/ rhubarb/ beet via redox titration with standard solution of $KMnO_4$./
OWTTE
Clear recognition, explicit mention of IV and DV is necessary for full marks.

(ii) Identify two controlled variables in the above experiment. [2]

Any two
1)Concentration of $KMnO_4$
2) Mass of Vegetable used
3) Type of spinach/ plants/ vegetable
3) Volume of water used to soak the water
4) Duration of soaking the vegetable in water / temperature of water (based on the IV above)

(b) The standard solution of standard $KMnO_4$ was prepared fresh and kept in a dark bottle and the burette and flask were covered with aluminium foil. This was to minimise the decomposition of $KMnO_4$ by sunlight.
Comment how this can affect the accuracy of experiment and explain how the volume of titre could be affected **if one fails to do so**. [2]

If one fails to do the above, sunlight will decompose $KMnO_4$. Hence, there will be less $KMnO_4$ in the solution/ more $KMnO_4$ is required to react with oxalate ion. [1]
The titre volume will be **higher**. [½]
Hence, the oxalate ion calculated will be more than the actual amount in the spinach. [½]

(c) After soaking the spinach in hot water for a period of time, the solution containing oxalate ion (extracted from 500.0 g of spinach) was transferred to a 250.0 cm^3 standard volumetric flask and the solution was made up to 250.0 cm^3 using tap water.
White solid appeared and was observed to settle at the bottom of the flask.
25.0 cm^3 of standard oxalate solution was then pipetted and titrated against 0.001 mol dm^{-3} of $KMnO_4$.
The average titre of 23.50 cm^3 of $KMnO_4$ was determined.

(i) Calculate the amount of oxalate ion in 25.0cm^3 of oxalate ion. [2]

Amount of $KMnO_4$ = 23.50/1000 X 0.001 =0.0000235 mol [1]
Amount of Oxalate ion in 25.0 cm^3 = 5/2 X 23.50/1000 X 0.001 = 0.00005875 [1]

(ii) State one assumption in your calculation and hence determine the concentration (ppm) of oxalate ion ($C_2O_4^{2-}$) in 500.0 g of spinach. [2]

Assumption: Leaching of oxalic from the spinach is equal to the amount of oxalic acid in plant. [1]
The ppm of spinach = [Mass of oxalate ion(in mg)] / [mass of spinach (in 1000g)]
Amount of Oxalate in 250 cm^3 = 0.0005875 mole [1/2]
Mr of Oxalate ion = 12.01X 2 + 16.01X 4 = 88.1 (no unit)
Mass of Oxalate = 0.05175g in 500.0g
Mass of Oxalate in 1000g = 103 mg in 1000g
Therefore concentration of oxalate ion in spinach = 103ppm [1/2]

(iii) The solubilities of some oxalate salts are given below.

Oxalate salt	Concentration (g dm^{-3})
MgC_2O_4	12.5
$Na_2C_2O_4$	26.9
CaC_2O_4	0.0067

[2]

Justify the identity of the white solid formed in (c).

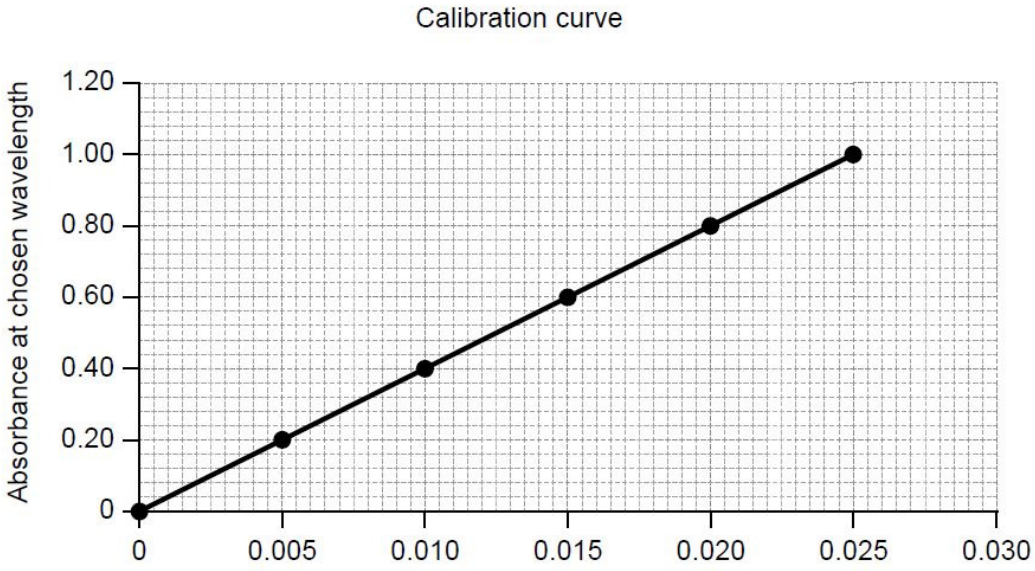
CaC_2O_4 [1]
Based on the data, it is the lowest among all and hence easiest to be precipitated. [1]

(iv) The formation of the white solid is a systematic limitation in this experiment. Suggest an improvement to overcome this. [1]

Tap water contains ions (like Ca, K and Na inside). Replaced this with de–ionised water. [1]
Reject filter the white solid.

(d) In another experiment, oxalate ion was complexed with the Iron (II) ion to form a yellow solution. The concentration of oxalate ions in the resulting solution is then determined from

a calibration curve, which is plotted by measuring the light absorbance of standard solutions.



(i) Deduce the relationship between absorbance and concentration. [1]

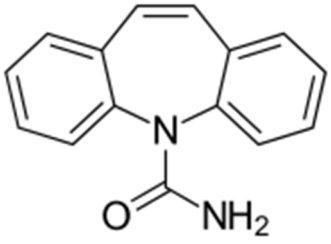
Absorbance is **directly proportional to concentration** of ethanoate ion

(ii) By interpolation of the graph above, determine the concentration of oxalate ion, $[C_2O_4^{2-}]$, when the absorbance measured is 0.08 A. [2]

At absorbance of 0.80 A ,the concentration is 0.02 $moldm^{-3}$ [1]
Since it is the linear relationship, the concentration of $C_2O_4^{2-}$ = 0.02 x 1/10 = 0.002 $moldm^{-3}$ [1]

Section B: Option D – Medicinal chemistry

2. Carbamazepine, $C_{15}H_{17}N_2O$, sold under the trade name Tegretol, is used primarily in the treatment of epilepsy and neuropathic pain. It is classified as a *narrow therapeutic index drug*. Common adverse effects include drowsiness, dizziness, headaches and migraines, motor coordination impairment, nausea, vomiting, and/or constipation. Synergistic effects with alcohol while taking carbamazepine may lead to enhanced depression of the central nervous system.



Carbamazepine

(a) Deduce the IHD of Carbamazepine. [1]

11 allow either approach (from MF or structure)
(Accept 8.5 from above provided MF)

(b) Comment on the solubility of the drug. [1]

Contains bulky / no polar benzene/ phenyl rings, making the molecule less polar/ more non-polar
Accept H-bond formation with water, [½]
Sparingly soluble in water/ polar solvents OR
soluble in non-polar solvents/ lipids. (Accepts any one correct answer) [½]
DONOT accept highly soluble in water.

(c) (i) Carbamazepine is tested by injection into mice to establish its LD_{50} and ED_{50} values. Distinguish between the two terms. [2]

LD_{50} is the amount/dose of a drug, which causes the death of 50% (one half) of a group of test animals/ OWTTE, must make reference to animal testing. [1]

ED_{50} is the amount/dose of a drug, which is required to achieve 50% of the desired response in 50% of the population/ OWTTE [1]

(ii) State the significance of the term "Therapeutic Index" in drug administration. [1]

The larger value of TI indicates that there is a wide margin between the toxic and effective dose, whereas a smaller value indicates that there is a narrow margin between the effective and toxic dose./ OWTTE.
OR
Importance in determining the margin of safety of a drug.
OR
Important indicator for therapeutic drug monitoring.

(d) Describe the term "synergistic effect". [1]

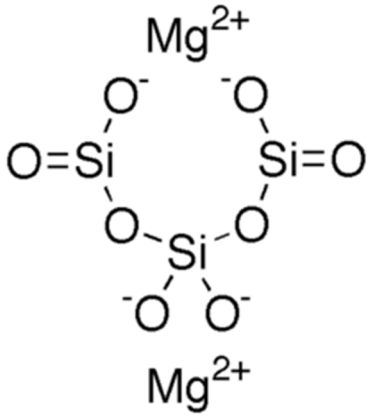
An interaction between two or more drugs taken at the same time that causes the total effect of the drugs to be greater than the sum of the individual effects of each drug/ owtte.

(e) State **one** advantage of combinatorial chemistry in drug synthesis. [1]

Any one

- synthesis of large numbers of compounds using a variety of starting materials;
- automated process reacts a small number of compounds with a variety of reagents;
- mix-and-split technique to produce a large number of products;
- library of many different but related compounds;
- compounds are tested for biological activity/effectiveness as possible drugs;
- parallel synthesis can produce smaller, more focused libraries;
- enables the production and testing of vast numbers of candidate medicines in a very short time.

3. Magnesium trisilicate is used as an antacid to treat indigestion and heartburns.



It reacts with hydrochloric acid in the stomach to form a soluble chloride salt, along with a colloidal mixture of silicic acid, H_2SiO_3, and silicon dioxide.

(a) Construct the balanced chemical equation for the reaction of magnesium trisilicate with HCl. [1]

$Mg_2Si_3O_8 + 4HCl \rightarrow 2H_2SiO_3 + SiO_2 + 2MgCl_2$

(b) Magnesium hydroxide is used as an antacid, however sodium hydroxide is not recommended for the treatment of stomach acidity.
Suggest why sodium hydroxide is not used in treating acidity of the stomach. [1]

Highly exothermic reaction, cause internal bodily damage and is therefore unsuitable
OR
Corrosive base that can denaturise / break the amide and ester links in proteins

(c) Evaluate whether 0.1 mol of magnesium trisilicate is a more or less effective antacid as compared to 0.1 mol of aluminium hydroxide. [2]

$Al(OH)_3 + 3\ HCl \rightarrow AlCl_3 + 3\ H_2O$ (donot penalize if equation not shown)

1 mol of $Mg_2Si_3O_8$ neutralizes 4mols of HCl, whereas 1 mol $Al(OH)_3$ neutralises only 3 mols of HCl. [1]
Hence magnesium trisilicate is more effective than aluminium hydroxide. [1]

ECF if balancing in (a) is wrong.

(d) Explain the action of Ranitidine (section 37 in data booklet) in controlling gastric acidity. [2]

Ranatidine is a H2-receptor antagonist drug. [1]
Blocks the action of histidine on the histamine H2-receptor in parietal cells. [1]
Thus inhibit the production of stomach acids.

(e) Aspirin shows two absorptions in the region 1700-1750 cm^{-1} in its infrared spectrum. These two absorptions are due to the two different carbonyl groups (C=O). [1]
Explain why they do not both occur at exactly the same frequency.

Although both carbonyl groups absorb infrared radiation in approximately the same region of the spectrum, however the precise frequency is determined by the other groups attached to the C=O group./ accept the C=O in ester and carboxylic acid environments show the different adsorptions, owtte

4. (a) Influenza A, also known as **H1N1**, is a respiratory disease caused by the *Alphainfluenzavirus*. It was responsible for the pandemic in 2009.
State what do **H** and **N** stand for? [1]

Hemagglutinin and neuraminidase (penalize spelling)

(b) Refer to the structure of Zanamivir in section 37 of the data booklet.

(i) Identify the number of chiral centres in the molecule. [1]

5

(ii) Describe the antiviral action of Zanamivir. [1]

Zanamivir works by binding to the active site of the neuraminidase protein/ enzyme [½], rendering the influenza virus unable to escape its host cell/ remains bounded to the host cell/ owtte[½] and cannot infect other cells.

(c) AIDS is treated using antiretroviral therapy which involves treatment with a mixture of antiviral drugs.
Discuss **two** difficulties, other than economic and socio-cultural issues, associated with the treatment of AIDS. [2]

Any relevant 2
- viruses mutate quickly so adapt to drugs/evade immune system response / *OWTTE*;
- viruses lack subunits/functions which can be targeted by antivirals / *OWTTE*;
- viruses cannot be killed and must be targeted on genetic level / *OWTTE*;
- each kind of virus usually requires special drugs/approaches / *OWTTE*;

(d) Explain why supercritical carbon dioxide has mainly replaced organic solvents to sustainably extract essential oils, from plant material. [1]

Any 1
- It can be easily recycled
- Supercritical CO_2 is universally accepted as a "friendly" and fully recyclable solvent/ It is much more environmentally friendly than organic solvents

- Single step extraction is tailored to achieve highly concentrated products/ After it has been used to extract a required product It evaporates easily making it easier to obtain the pure product
- Chemically inert.
- Non flammable
- Have good solvent characteristics for non-polar and slightly polar solutes.
- It is easily removed from the product
- Allows the obtaining of extracts whose flavour and taste are perfectly conserved and reproducible.
- It dissolves solutes at a lower temperature than organic solvents so there is less likelihood of the extracted product thermally decomposing or becoming denatured.

5. (a) Taxol is an anticancer drug with a complex structure with multiple chiral carbon centres (section 37 of data booklet).

(i) State the action of Taxol in chemotherapy. [1]

Taxol interferes with tumour cell division [½]
by binding to certain proteins called tubulins. [½]

(ii) Taxol can be made by *semi–synthesis*. Explain the meaning of this term. [1]

Semi-synthesis of the drug, starting with a precursor from nature, allowed it to be made on a larger scale and reduced the environmental impact.

(b) Describe how chiral auxiliaries can be used to synthesise only the desired enantiomeric form of a drug from a non–chiral compound. [3]

- a chiral auxiliary is itself an enantiomer/ optically active isomer; [1]
- it is bonded to the non-chiral reactant molecule to create the stereochemical conditions necessary to follow a certain pathway;[1]
- once the desired enantiomer is formed the auxiliary is removed;[1]

(c) Outline how the waste of technetium–99m, a low level metastable radionucleotide, might be treated. [1]

Stored for several days, until the emitted radiation is very low, then buried.

(d) Technetium–99m is generated in a hospital from molybdenum–99.

(i) Using section 6 of the data booklet, deduce the nuclear equation for the radioactive decay of technetium–99, when it emits beta radiation. [1]

$$^{99}_{43}\mathrm{Tc} \rightarrow {}^{99}_{44}\mathrm{Ru} + {}^{0}_{-1}\mathrm{e}^{-}$$

(ii) A patient is given 0.05 mg of technetium–99m, which has a half–life of 6.0 hours. Calculate how much time would elapse until the radioactive isotope decays to 6.3×10^{-3} mg. You may refer to section 1 and 2 of the data booklet. [2]

$\lambda = \frac{0.693}{t_{1/2}} = \frac{0.693}{6} = 0.1155$ [½]

$\frac{N_t}{N_o} = e^{-\lambda t}$; $\ln(\frac{6.3 \times 10^{-3}}{0.05}) = -0.1155\ t$ [1]

t=17.93 h ≈ 17.9 h / accept 18 h [½]

(e) Methyltestosterone is a banned synthetic steroid, which may be used illegally by athletes to enhance performance.
Suggest the analytical method(s) that can be used to detect the presence of these compounds in the urine sample of an athlete. [1]

Gas/ liquid chromatography : [½] and Mass spectrometry[½]

*(The urine is injected into a **gas/liquid chromatography** machine and carried by an inert gas through the heated liquid stationary phase (e.g. a long-chain alkane) coated onto a solid support in a long thin capillary tube contained inside an oven. This process separates the components. As the different components are eluted at the end of the column they are passed into a **mass spectrometer**. The mass spectrum for each component is compared with the spectra of known compounds and a printout obtained of all the separate compounds and their concentrations in the urine is produced)*