Name	Candidate Number

Anglo-Chinese School (Independent)

YEAR 6 PRELIMINARY EXAMINATION 2023
INTERNATIONAL BACCALAUREATE DIPLOMA PROGRAMME
CHEMISTRY HIGHER LEVEL

PAPER 3

Tuesday **12th September 2023** **1 hour 15 minutes**

INSTRUCTIONS TO CANDIDATES

- Do not open this examination paper until instructed to do so.
- Write your **candidate session number in the box above**.
- A calculator is required for this paper.
- A copy of the Chemistry Data Booklet is required for this paper.
- Write your answers in the boxes provided.
- If you use additional sheets of paper for your answer, attach them to the booklet. Indicate the question number clearly on these sheets.
- All drawings must be in ink.

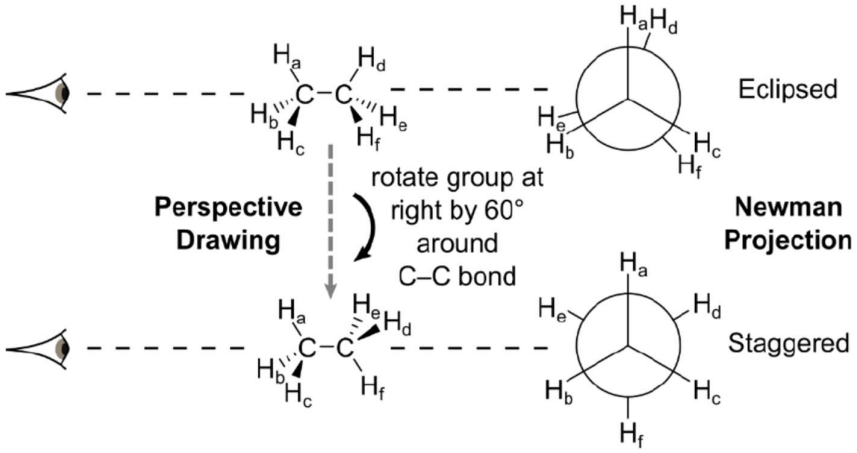
For examiner's use	
Qn 1	/6
Qn 2	/9
Qn 3	/4
Qn 4	/6
Qn 5	/5
Qn 6	/6
Qn 7	/5
Qn 8	/4
Wrong s.f. /units	
Total	/45

This question paper consists of 15 printed pages including this cover page.

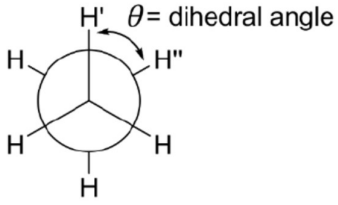
Section A

Answer **all** questions. Answers must be written in the answer boxes provided.

1. Molecules that have a different arrangement as a result of bond rotation are called conformers. Conformers can be represented by the Newman projection. A Newman projection views the carbon-carbon bond directly end-on and represents the two carbon atoms by a circle. Bonds attached to the front carbon are represented by lines to the centre of the circle, and bonds attached to the rear carbon are represented by lines to the edge of the circle. Ethane can have two conformers as a result of the bond rotation: staggered and eclipsed.



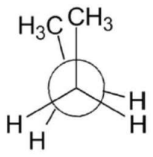
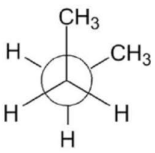
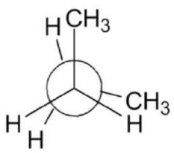
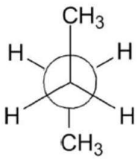
Using the Newman projection, the angle between the C-H bonds of the front carbon and the C-H bonds on the back carbon is known as the dihedral angle.



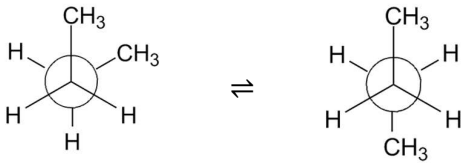
Butane can have four types of conformers as a result of bond rotation. **Table 1** shows the four conformers of butane. The gauche conformer occurs when the dihedral angle between the methyl groups are 60° apart and the anti conformer occurs when the dihedral angle is 180° apart.

(This question continues on the following page)

(Question 1 continued)

Conformer	Fully eclipsed	Staggered (Gauche 1)	Eclipsed	Staggered (Anti)
Newman projection				
Dihedral angle between the methyl groups	0°	60°	120°	180°

An equilibrium between the gauche 1 and the staggered (anti) conformer can be achieved:



The equilibrium constant, K_c, between the gauche 1 and the staggered (anti) conformer at 298 K can be calculated by the equation given below:

$$-3630 = -RT \ln K_c$$

R = molar gas constant in J mol^{-1} K^{-1}

T = temperature in Kelvins

(a) Which of the two conformer of butane is the most stable? Explain your answer. [1]

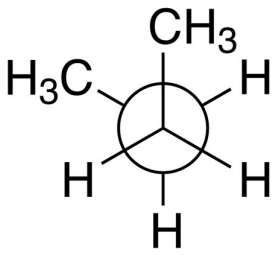
Anti conformer is most stable as the two bulky groups are furthest from each other / it has the lowest potential energy / $K_c > 1$ / $\Delta G < 0$ so forward reaction is more spontaneous.

Marker comments:

Generally well done. A good handful of candidates interpreted the question wrongly, not recognising that the question is asking for one out of the two conformers given in the equilibrium. Although not penalised, candidates are advised to always read the context given to address the question correctly.

Some candidates seemed to think that the different conformers are structural isomers. They should take note conformers are **different spatial arrangements of the same compound** due to the free rotation of sigma bonds.

(b) (i) There are two gauche conformers of butane. With reference to Gauche 1, draw the other gauche conformer of butane. [1]



Marker comments:

Generally well done.

(ii) At equilibrium, butane will consist the staggered (anti) conformer and the two gauche conformers. Calculate the equilibrium constant K_c for the equilibrium between the gauche 1 and the staggered (anti) conformer of butane at 298 K. Hence, calculate the percentage of the staggered (anti) conformer of butane at 298 K by using section 2 from the Data Booklet. [3]

$-3630 = -RT \ln K_c$

$-3630 = -8.31 \times 298 \ln K_c$

$\ln K_c = 1.466$

$K_c = 4.331 = \frac{[anti]}{[gauche\ 1]}$

[anti] = 4.331 [gauche 1]

Let [gauche 1] = x = [gauche 2]

Total concentration = [anti] + [gauche 1] + [gauche 2] = 4.331 x + 2x = 6.331 x

Percentage of anti conformer = $\frac{4.331\,x}{6.331\,x} \times 100\ \%$ = 68.4%

Alternative mark scheme:

anti ⇌ gauche 1 + gauche 1a

$K_c = 4.331 = \frac{[anti]}{[gauche]^2}$

Let the percentage of anti = x %

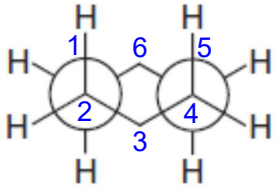
$K_c = 4.331 = \dfrac{x}{\left(\left(\frac{100-x}{2}\right)\right)^2}$

x = 90.8 %

Marker comments:

Not well done. Majority of the candidates calculated the K_C value but unable to interpret the information about the equilibrium between anti and the ***two*** gauche conformers to calculate the percentage of anti conformer (within the 3 conformers).

(d) A Newman projection for Compound X is shown below. State the IUPAC name for Compound X. [1]



Cyclohexane

There are 6 carbon atoms connected in a ring.

Marker comments:

Very poorly done. Most candidates either could not recall that the intersection of two lines represents a carbon atom in skeletal structure or understand from the question that the circle represents a carbon atom in the Newman projection structure.

2. The Finkelstein reaction is a nucleophilic substitution reaction and is carried out using dry propanone as a solvent.

One example of the Finkelstein reaction is given.

$$CH_3CH_2CH_2Br + NaI \rightleftharpoons CH_3CH_2CH_2I + NaBr$$

(a) (i) Explain why it is important for propanone to be dry. [1]

H_2O is a **nucleophile** which can **interfere/take part in the reaction**.

To prevent **hydrolysis of 1–bromopropane**

Marker comments:

Candidates' answers were rather varied.

Common answers that were **not** accepted:
- H_2O is a polar protic solvent, which reduces the rate of S_N2

Although this is a true statement, it is not relevant in this question as the concern with ***non-dry propanone*** is not about the minute amount of water replacing the bulk of propanone as the solvent.

- H_2O reacting with propanone

Nucleophilic substitution / hydrolysis / reaction of propanone with water is not feasible as propanone is relatively much more stable than the gem-diol product.

(a) (ii) The solubilities of NaBr and NaI in propanone are shown.

compound	solubility at 25 °C in g / 100g of propanone
NaBr	0.00841
NaI	39.9

Use this information to explain why the reaction produces a very high yield despite being a reversible reaction. [1]

Solubility of **NaBr** in propanone is very low, hence **will precipitate out** as solid, its **concentration decreases and shifts the position of equilibrium to the right**, favouring the formation of products.

Marker comments:
Generally well done.

(b) State and explain **one** precaution, other than using protective equipment such as hand gloves, a lab coat or eye protection, that should be taken when carrying out this experiment. [1]

Organic compounds / solvents are flammable AND should not be used near naked flame / direct heat source

OR
Organic compounds / solvents are volatile / toxic / irritant to respiratory system / may cause dizziness / drowsiness AND should be used in a fume cupboard / fumehood / be properly disposed into organic waste bin

OR
NaI used in powder form to prepare standard solution can reach harmful concentration of airborne particles, which is irritating to the eyes, skin and respiratory tract AND should be used in a fume cupboard / fumehood / handled with the use of facial mask

OR
Iodide ions / 1–iodopropane can be oxidised by air / oxygen in air / to form I_2, which is volatile / toxic / irritant to respiratory system AND should be used in a fume cupboard / fumehood

OR
Iodide ions / 1–iodopropane is photosensitive and can form I_2, which is volatile / toxic / irritant to respiratory system AND should be used in a fume cupboard / stored in a opaque bottle

Marker comments:
Candidates' answers were rather varied but a good number were able to give the intended answers.

Some candidates did not read the question carefully, the phrase 'other than using protective equipment such as hand gloves, a lab coat or eye protection' suggests that a safety precaution in the context of this experiment is expected.

Standard safety protocols such as washing of hands after experiment, no eating / inhaling of chemicals, careful handling of glasswares, proper disposal of chemicals etc should not be given. Candidates should be familiar with some specific safety precautions covered in the IA practicals.

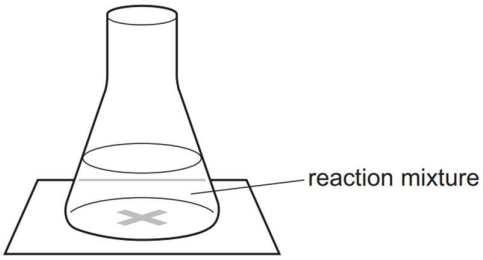
(c) A student plans an experiment to show that the rate of the reaction is proportional to the concentration of NaI.

Propanone is used as the solvent in this reaction.

$CH_3CH_2CH_2Br$ (pr) + NaI (pr) $\rightleftharpoons$ $CH_3CH_2CH_2I$ (pr) + NaBr (s)

(pr) = substance is dissolved in propanone

The student plans to record the time it takes for the solid formed to obscure a cross on a piece of paper below the conical flask, as shown.



To carry out this experiment, the following materials are available.

- $CH_3CH_2CH_2Br$ (l)
- NaI (s)
- dry propanone, CH_3COCH_3 (l)
- usual laboratory apparatus

(i) The student recorded data in the table below. [2]

Complete the table with appropriate volumes that the student could have used in four further experiments.

volume of 0.5 mol dm^{-3} NaI (pr) / cm^3	volume of $CH_3CH_2CH_2Br$ (l) / cm^3	volume of CH_3COCH_3 (l) / cm^3	total volume / cm^3	time / s
10.0	2.0	30.0	42.0	
15.0	2.0	25.0	42.0	
20.0	2.0	20.0	42.0	
25.0	2.0	15.0	42.0	
30.0	2.0	10.0	42.0	

$1.0 \leq V_{NaI} \leq 40.0, \neq 10.0\ cm^3$
$V_{NaI} + V_{CH3COCH3} = 40.0\ cm^3$
$V_{CH3CH2CH2Br} = 2.0\ cm^3$

regular intervals not needed

Marker comments:

Generally well done for candidates who recognised that this is a stop clock reaction and the aim of the experiment is to prove that rate of the reaction is proportional to the concentration of NaI. Hence, **only the volume of NaI standard solution is varied while keeping the total volume constant**.

The purpose of the propanone being the solvent, is to keep total volume constant so that **volume of NaI standard solution used is directly proportional to its concentration in the reaction mixture**. Propanone is not taking part in the reaction.

Any other suggestion that changes the total volume of solution for all experiments, even if calculated concentration of NaI and $CH_3CH_2CH_2Br$ are varying and kept constant respectively, is not accepted as this affects the depth of solution for every experiment and hence the time measurement. This defeats the purpose of doing stop clock and is not feasible in practice.

(c) (ii) Write an expression to show how the student could calculate the rate of the reaction. [1]

rate = $\frac{1}{\text{time}}$ / = $\frac{1}{t}$ / = $\frac{\text{mass of NaBr}}{t}$

Marker comments:

Not well done. Many candidates interpreted that question wrongly, giving the rate expression. In the context of the question, which is a stop clock method, the question is asking for **how you can calculate the rate using the data collected in the procedure**.

Quite a handful of candidates do not understand the chemistry behind the stop clock method. Since the time measured is to obscure 'X' (**for a fixed amount of NaBr product to form**),

$$\text{rate} = \frac{d[NaBr]}{dt} = \frac{dm_{NaBr}}{dt} \approx \frac{m_{NaBr}}{t}$$

relative rate = $\frac{1}{t}$ when mass is kept constant for all experiments.

The amount or concentration of reactants are usually not used up by the time measured and hence cannot be used to calculate the rate.

(iii) Suggest **one** systematic error and **one** random error associated with this procedure assuming no human errors occurred and the stopwatch was accurate. [2]

Systematic error:

- The rate is an approximation / underestimate of the initial rate
- No temperature control over the duration of reaction / reaction may be endothermic/exothermic affecting the rate of reaction
- Organic compounds evaporate, affecting concentration / depth of solution
- No stirring over duration of solution / non-homogeneous solution
- Reaction is reversible / some NaBr remained dissolved, hence takes longer than expected to reach the end-point
- Position of observation/person observing

Random error:

- No replicate for each experiment
- Reaction might be too fast / timing too short AND high percentage uncertainty
- Volume of certain reagents used is low, hence significant % uncertainty in measurement

- Volume of reagents measured to 1 decimal place / less precise apparatus used for measurement of volume, hence significant % uncertainty in measurement
- Intensity of lightning in the lab

Any logical suggestion

Marker comments:

Generally well done for candidates who understood the chemistry in this practical.

Common mistakes included:

- Confused between systematic and random error

Systematic error results in the measured values always deviating from the "true" value consistently in the **same** direction. **Random errors** arise from the imprecision of measurements and can lead to readings being **above or below** the "true" value.

- Incomplete dissolution of NaI in the reaction mixture

However, it was shown in the table that a NaI standard solution, with a concentration well below the solubility, is used in experiment. Hence, this is invalid.

- Any errors due to poor experimental skills such as miscalibration, parallax error, unclean apparatus, contamination of chemicals, spillage of chemicals during transfer etc should be avoided.

Candidates should be familiar with some methodological and procedural errors (when provided in question) especially for the techniques covered in the IA practicals.

(iv) Suggest an improvement to the experiment to improve the accuracy of the measurement of rate. [1]

Use more concentrated solution for faster reaction / more accurate approximation of the initial rate

Use initial rate method / continuous method

Any physical / chemical technique to replace the observation using human eye

Use thermostatically controlled water bath

Use a lid to cover the conical flask

Use a magnetic stirrer / swirl after mixing the reagents

Standardise unstable compounds such as sodium iodide solution to obtain accurate concentration

Any logical suggestion to overcome the systematic errors mentioned in (iii)

Marker comments:

Generally well done for candidates who understood the chemistry of the stop clock method.

Quite a significant number of candidates did not know that to **improve accuracy**, **systematic** errors (and not random errors) need to be removed. When random errors are removed, precision is improved.

A common mistake is to use redox titration with thiosulfate to quantify iodide ions but thiosulfate is a reducing agent, which reduces iodine (I_2) to iodide ions. Although it is not penalised, it would be good to know some of the common chemicals used in acid-base, redox, complexometric titrations etc so that candidates can suggest correct chemicals to use in the continuous method in following rate of a given reaction.

Likewise, in this experiment, NaBr solid is formed to obscure the 'X', so change in colour of solution is not suitable to follow the rate of this reaction. Measurement of opacity or conductivity of the reaction mixture is more feasible for this reaction.

Section B

Option D – Medicinal chemistry

Answer **all** questions. Answers must be written in the answer boxes provided.

3. Opiates such as morphine and codeine have been used for thousands of years to alleviate pain and are derived from opium.

(a) Morphine is typically administered parentally to improve its bioavailability. Outline the meaning of the bioavailability of a drug. [1]

fraction/proportion/percentage of «administered dosage» that enters blood/plasma/ circulation OR Accept "fraction/proportion/percentage of «administered dosage» that reaches target «part of human body»".

Marker comments:
Very well done

(b) (i) Diamorphine (heroin) can be synthesised from morphine. Identify the reagent necessary for this reaction using section 37 of the data booklet. [1]

$(CH_3CO)_2O$ OR CH_3COCl OR CH_3COOH

Marker comments:
Very well done

(b) (ii) Explain why diamorphine (heroin) is more potent than morphine. [2]

morphine has «two» hydroxyl groups AND diamorphine has «two» ester/ethanoate/acetate groups
OR molecule of diamorphine is less polar than morphine
OR groups in morphine are replaced with less polar/non-polar groups in diamorphine ✓
«less polar molecules» cross the blood–brain barrier faster/more easily
OR diamorphine is more soluble in non-polar environment of CNS/central nervous system than morphine ✓
Accept "alcohol/hydroxy" for "hydroxyl" but not "hydroxide".
Accept "fats" for "lipid".
Accept "heroin" for "diamorphine".

Marker comments:
Very well done

4. Penicillin was one of the first antibiotics to be isolated and identified for its ability to treat bacterial infections.

(a) Describe how penicillin combats bacterial infections with reference to its structure. Refer to section 37 of the data booklet. [2]

Any two of:
beta-lactam ring is «sterically» strained
OR
ring breaks up/opens/reacts «easily»
OR
amide/amido group «in ring» is «highly» reactive ✓

«irreversibly» binds/bonds to enzyme/transpeptidase
OR
inhibits enzyme/transpeptidase «in bacteria» that produces cell walls
OR
prevents cross-linking of bacterial cell walls ✓

cells absorb water ***AND*** burst
OR
cells cannot reproduce ✓

Marker comments
Generally well answered.

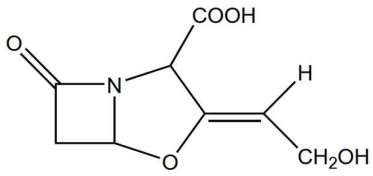
(b) Some antibiotic-resistant bacteria produce a beta-lactamase enzyme which destroys penicillin activity. Various responses to the challenge of antibiotic resistance have been developed.

(i) Discuss **two** ways in which human activities have caused an increase in resistance to penicillin in bacterial populations. [2]

Overuse of antibiotics in animal stocks / food chain;
over-prescription;
failure of patients to complete treatment regimen.
Inappropriate disposal of penicillin from factories.

Marker comments:
Generally well answered.

(b) (ii) Suggest how adding clavulanic acid to penicillin enables the antibiotic to retain its activity. [1]



Clavulanic acid

beta-lactam/four-membered ring «in clavulanic acid» reacts with enzyme/beta-lactamase
Accept "acts as enzyme inhibitor/suicide substrate/preferentially binds to enzyme"

Marker comments:
This question is poorly attempted. Students are required to mention the beta-lactam ring and the purpose which is to react with the beta-lactamase/penicillinase.

(c) A doctor prescribes a broad-spectrum antibiotic for a patient, then some days later prescribes a narrow-spectrum antibiotic. [1]

State the main disadvantage of using a broad-spectrum antibiotic.

kills beneficial/useful bacteria;
Do not accept good or friendly bacteria

Marker comments
This question is poorly attempted. Many answered the question in the context of increasing antibiotic resistance, which is incorrect.

5. (a) Explain how omeprazole (Prilosec) reduces stomach acidity. [2]

Inhibits the secretion of stomach acid/H^+ [1m] prevent transportation of H^+ into the stomach.

Active metabolite bind irreversibly to the receptors of the proton pump [1m]

Accept proton pump inhibitor
Accept H^+/K^+ ATPase for proton pump

Markers comments
Generally well answered.

(b) The pH inside most cells is maintained at around 7.4 by a phosphate buffer made up of $H_2PO_4^-$ (aq) ion and HPO_4^{2-} (aq). The pK_a of $H_2PO_4^-$ (aq) is 7.2. [3]

A typical value for the total phosphate concentration in a cell, $[H_2PO_4^-] + [HPO_4^{2-}]$ is 0.020 mol dm^{-3}. Calculate the value of $[HPO_4^{2-}]$ inside a cell.

$[H_2PO_4^-] + [HPO_4^{2-}] = 0.020$

$[H_2PO_4^-] = 0.020 - x$

$pH = pKa + \lg\frac{[salt]}{[acid]} = 7.2 + \lg\frac{x}{0.020-x} = 7.4$

$\lg\frac{x}{0.020-x} = 0.2$

$\frac{x}{0.020-x} = 1.584$

$x = 1.584\ (0.020 - x)$

$x = 0.03168 - 1.584\ x$

$2.584\ x = 0.03168$

$x = 0.0123$ mol dm^{-3}

Marker comments:
Generally well answered.

6. (a) Antiviral medications such as zanamivir (Relenza) are commonly available for commercial use. [2]

Identify the names of two functional groups present in zanamivir using section 37 of the data booklet.

Hydroxyl, carboxyl/carbonyl, ether, amido (any two)

Accept alcohol, carboxylic acid, amide/carboxamide, amine, alkenyl/alkene/ C=C double bond

Marker comments
Generally well answered.

(b) Discuss **two** difficulties associated with solving the AIDS problem. [2]

Any two of:

Viruses lack cell structure so difficult to target with drugs

HIV is a retrovirus
OR
HIV genetic material is in the form of RNA instead of DNA

HIV affects/destroys helper/T-cells which are necessary to fight infection.
HIV has great genetic diversity so difficult to produce a vaccine.
Anti-retroviral agents are expensive so not everyone/country can afford them.

Socio-cultural issues deter people from seeking treatment/prevention/diagnosis.
OR
Lack of education/conversation/stigma associated with being HIV positive

Mutation of virus/HIV
Virus/HIV metabolism linked to that of host cell
Drugs harm host cell as well as virus/HIV
HIV difficult to detect/ remains dormant.

Marker comments
Generally well answered.

(c) Oseltamivir was commercially produced from shikimic acid, a precursor which is a metabolite in micro-organisms and plants. [2]

Outline how green chemistry was used to develop the precursor for oseltamivir in order to overcome the shortage of the drug during the flu season.

Using genetically modified/ GM E. Coli/ bacteria/ microorganisms

Accept E. Coli/ bacteria biosynthesis OR E. Coli/bacteria undergo fermentation OR cells of the bacteria are broken down to form precursor/ shikimic acid

Use readily available cyclic ester/ lactone OR forms the correct stereoisomer of oseltamivir in a shorter number of chemical steps.

Do not accept planting more Chinese star anise or other plant sources of shikimic acid.

Marker comments
Generally well answered. A number of students are unable to give the answer on using a cyclic ester for synthesis.

7. Technetium-99m is the most commonly used isotope for diagnostic medicine.

(a) Discuss the properties that make Technetium-99m suitable for diagnosis. [3]

Any three of:
«easily» detected/traced
OR
«gamma-radiation of approximately» same frequency as X-rays «so can be detected using existing X-ray equipment»

short/intermediate half-life «hence does not remain in body for long time»

weak ionizing radiation «less harmful»
OR
low amount of radiation produced «so less harmful»
OR
energy of photons is low

form «variety of» compounds that are absorbed by «different» organs
OR
«chemically» binds to many biologically active compounds

excreted quickly «from body»

Marker comments
Generally well answered.

(b) Technetium-99m has a half-life of 6.03 hours. Calculate the time taken, in day, for 85% of Technetium-99m to decay [2]

Alternative 1:

$N = N_0(0.5)^{\frac{t}{t_{1/2}}}$

$0.15 = 1(0.5)^{\frac{t}{6.03}}$

t = 16.5 hours = 0.688 day

Alternative 2:

$\lambda = \frac{ln2}{6.03} = 0.1149\ hr^{-1}$

$N = N_0\ e^{-\lambda t}$

$\ln 0.15 = -(0.1149)t$

$t = -\frac{\ln 0.15}{0.1149}$

= 16.5 hours = 0.688 day

Markers comments

Generally well answered, except that a number of students did not convert the half-life to day.

8. (a) A mixture of 0.250 mol ethyl ethanoate, 0.100 mol ethanol and 0.380 mol ethanoic acid is separated by fractional distillation. [2]

The vapour pressure of pure ethanol at 20 °C is 5.95 kPa.
Calculate the vapour pressure of ethanol above the liquid mixture at 20 °C.

$\frac{0.100}{0.250+0.100+0.380}$ x 5.95 kPa

= 0.815 kPa

Marker comments

Generally well answered.

(b) Taxol is a cancer drug.

(i) State the feature of Taxol that is major challenge of the synthesis, using section 37 of the data booklet. [1]

Numerous stereoisomers/chiral carbons/chiral centres/stereocentres/optical isomers/ many enantiomers formed.

Accept exact number of chiral carbons ie 11, but do not accept just “chiral”.

Markers comments:
Generally well answered

(ii) Describe how challenge in (b)(i) was resolved by pharmaceutical companies. [1]

chiral auxiliaries/molecule binds to reactant blocking one reaction site «by steric hindrance»
OR
asymmetric synthesis / enantioselective catalysis «producing a specific enantiomer»
OR biosynthesis / genetically modified bacteria/microorganisms ✓

Accept “use of a chiral auxiliary leading to «the synthesis of» the desired enantiomer”.

Markers comments:
Generally well answered.