Data-based Questions (Organic Chemistry)

Instructions for Practice

These questions are data-based questions. You need to apply your knowledge to novel scenarios. Although the focus of this problem-set is on Organic Chemistry, other topics from H2 Chemistry are also included.

Usually, each question has a theme. The theme for each question is listed here, but it will be explicitly listed in your exams.

In Paper 2, data-based questions will take up about 20 to 25 marks of the paper. You should allocate slightly more time to solve these data-based questions. The ideal time allocation for each question is 1.5 minutes per mark.

All questions in this set are original, and it is most likely that you will be seeing these questions for the first time.

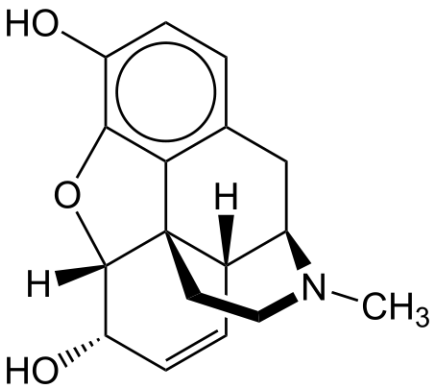
Happy revising!

Question number and Theme		Maximum Marks	Suggested time allocation
1	The synthesis of narcotics	20	35 minutes
2	Group 14 elements	20	35 minutes
3	All about archaea	25	42 minutes

1 Many illicit drugs found in the world are synthesised from naturally occurring organic compounds.

Known for its addictive properties, heroin is an illegal substance banned across the world. Heroin is not a natural product—it is produced from morphine found in opium.

The skeletal structure of morphine is provided below.



Morphine ($C_{17}H_{19}NO_3$)

(a) Stage 1: Extracting the morphine from raw opium

The raw opium was crushed. It was then mixed with hot water.

The composition was stirred until it became a homogenous suspension. The pH value was 8. Then calcium oxide was added, together with more hot water. The suspension was filtered, and the filtrate left to stand overnight. Further processes were made to ensure that more morphine was extracted from the residue.

To this filtrate, ammonium chloride was added. Solid morphine precipitated from the filtrate. The precipitate was collected through filtration.

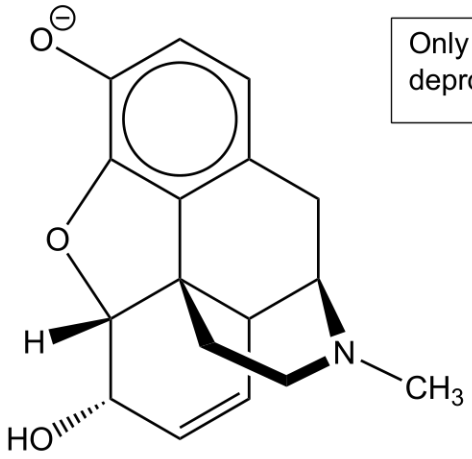
(i) Write down **four** functional groups found in morphine. State the functional groups that contribute to the amphoteric nature of morphine. [3]

Any 4: alkene, (tertiary) amine, alcohol, phenol, ether
Amphoteric nature of morphine: amine (basic), phenol (acidic)

……

(ii) Draw the predominant form of morphine after calcium oxide was added to the opium suspension. [1]

The carbon framework is given to you below.



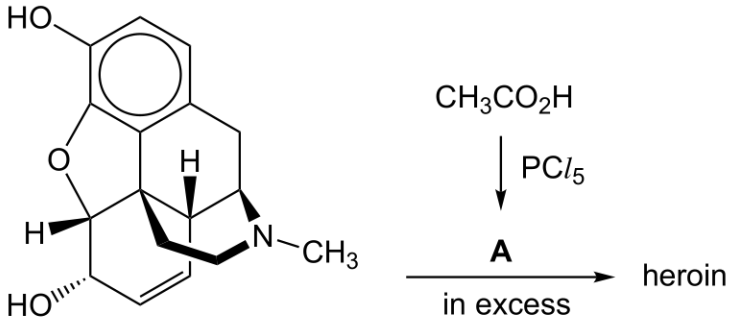
Only the phenol group is deprotonated.

(iii) Explain why after solid ammonium chloride was added, morphine precipitated from the filtrate. [2]

Ammonium chloride protonates the phenoxide of deprotonated morphine. In doing so the ion-dipole interactions between the deprotonated morphine are disrupted. Molecular morphine (that is not deprotonated or protonated) does not form favourable interactions with water as the dispersion forces between molecular morphine and water does not overcome the predominant hydrogen bonding in water.

(b) Stage 2: Conversion of morphine to heroin

Heroin can be synthesised with Scheme 1.



Scheme 1

(i) Name **A**. [1]

ethanoyl chloride (accept acetyl chloride)

(ii) White fumes were reported to be evolved when heroin is synthesised using Scheme 1.

Name what constitutes the white fumes and hence explain why amateur drug makers do **not** use Scheme 1 to make heroin. [1]

hydrogen chloride (reject hydrochloric acid, reject writing chemical formula since question states "name")
hydrogen chloride is an eye-irritant, and will be produced in large quantities. (credit is given to a health hazard related to hydrogen chloride gas)

(iii) Instead of using **A**, amateur drug makers use acetic anhydride $(CH_3CO)_2O$.

After the reaction, sodium carbonate was added. Effervescence was observed, together with precipitation of heroin.

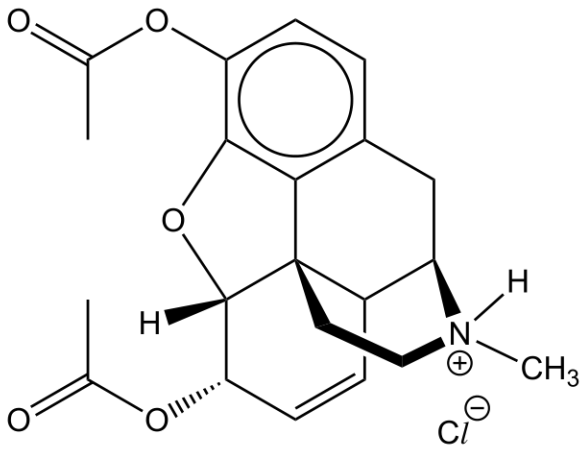
Suggest an equation to account for the effervescence. [1]

$2\ CH_3CO_2H + Na_2CO_3 \rightarrow 2\ CH_3CO_2^-Na^+ + CO_2 + H_2O$

(iv) Heroin precipitated was filtered and retained. It was then washed and purified with aqueous ammonia. Finally, the purified heroin was dissolved in hydrochloric acid and a small amount of propanone. After evaporating the propanone, a white crystalline product was obtained.

Draw, with stereochemistry, the structure of this white crystalline product. [2]

The carbon framework is given to you below.



Both the phenol and alcohol will undergo a condensation reaction with ethanoyl chloride / acetic anhydride. The question also states that heroin is dissolved in hydrochloric acid and crystallised. So the hydrochloride salt of heroin is obtained. The N atom is protonated.

Credit given for (1) correct acylation (2) showing protonation of heroin + chloride counterion

(v) In a run to synthesise heroin, 3.9 kg of heroin (in the form of the white crystalline product in **(iv)**) was obtained from 7.8 kg of morphine.

Determine the percentage yield of heroin in this run. [2]

Molecular formula of morphine is $C_{17}H_{19}NO_3$ (M_r = 285)
Molecular formula of heroin (white crystalline form) is $C_{21}H_{24}NO_5Cl$ (M_r = 405.5)

$$\text{Yield} = \frac{\frac{3.9}{405.5}}{\frac{7.8}{285}} \times 100\% = 35.1\%$$

(vi) Heroin is more potent than morphine. When heroin is synthesised, small traces of unreacted morphine are still present in the heroin product. A higher purity of heroin often begs a higher price tag because it gives the user more pleasure with a smaller dose.

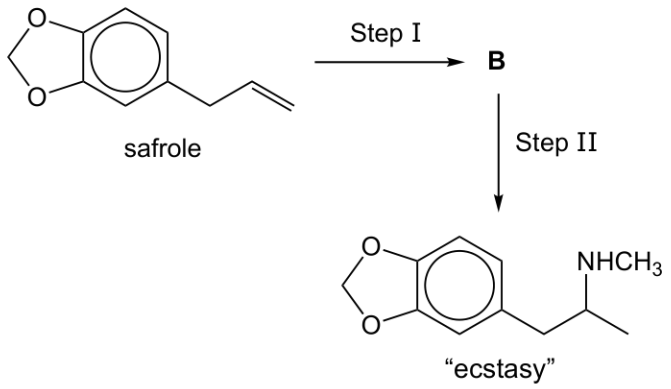
A drug dealer claims he has "pure heroin" in the powdered form.

Suggest a simple chemical test to examine whether the heroin is contaminated with morphine. [2]

Add neutral aqueous iron(III) chloride. If the solution turns violet, heroin is contaminated with morphine. If the solution remains yellow/orange, heroin is not contaminated with morphine.

Reject answers using Br_2(aq) (C=C double bond present), testing for presence of –OH (e.g. using Na) (sample is in solid phase). Only accepted answer is above (tests for phenol group which is only present in morphine).

(c) "Ecstasy" is another illicit drug that can be synthesised from the naturally occurring compound safrole. Safrole can be found in Japanese star anise and the sassafras tree.



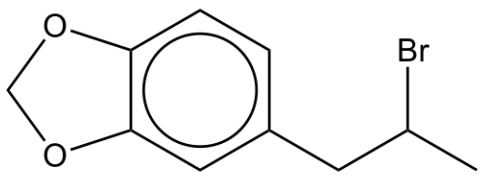
Scheme 2

(i) Refer to Scheme 2. Suggest the reagent(s) and conditions for Step I, Step II and a structure for the intermediate **B**. [2]

Step I: HBr(g), r.t. (accept HC*l*, HI)

Step II: (excess) CH_3NH_2, heat (with reflux)

B

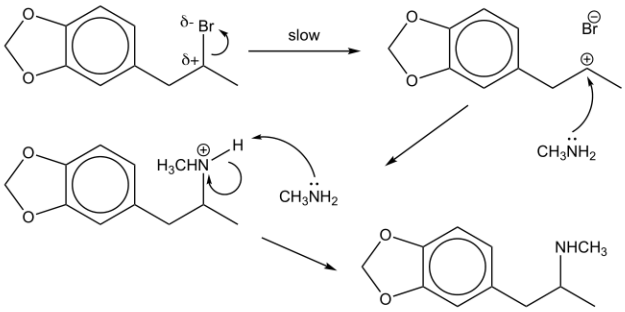


product must follow through from Step I

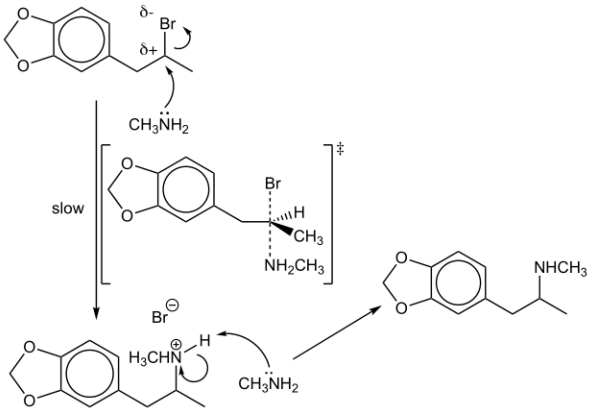
(ii) Describe the mechanism for the conversion of **B** to "ecstasy". Indicate any relevant lone pairs and dipole moments clearly. [3]

Accept S_N1 or S_N2 mechanisms

S_N1 (slow step labelled, deprotonation of amine must be shown for full credit)



S_N2 (slow step labelled, transition state, deprotonation of amine must be shown for full credit)



[Total: 20]

2 While carbon is an essential part of life, other Group 14 elements find important uses in organic chemistry and applications in everyday life.

(a) The mechanism regarding the hydrolysis of chlorosilanes was not widely known. However, kinetic studies were able to determine this mechanism.

Chlorosilanes have the general formula R_3SiCl. You may assume that the Si atom is sp^3 hybridised.

(i) Use the following facts to explain why the hydrolysis of chlorosilanes does **not** follow a S_N1 nor S_N2 type reaction.

- The relative rate of hydrolysis of SiX_4 (where X is a halogen) decreases as such: SiF_4, $SiCl_4$, $SiBr_4$, SiI_4. (Assume that the mechanism of the hydrolysis of SiX_4 is the same as the hydrolysis of chlorosilanes.)

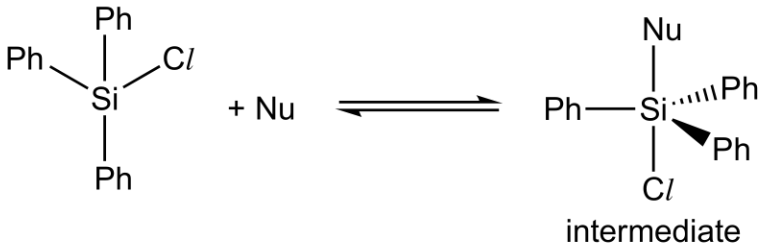
- The overall order of reaction is three. [3]

Suppose the hydrolysis follows a S_N1 or S_N2 mechanism. Then the breaking of the Si—X bond is the rate-determining step. Since the Si—X bond is weaker down Group 17, the rate of hydrolysis will increase down Group 17 for X. However, this is not the case.

For the S_N1 mechanism, the overall order of reaction is one, while for the S_N2 mechanism, the overall order of reaction is two. Neither of these is the case for the hydrolysis of the chlorosilane.

Hence, the S_N1 and S_N2 mechanism does not apply.

Step 1 of the hydrolysis of Ph_3SiCl (Ph = C_6H_5) is aided by a nucleophile, Nu. This is represented as an equilibrium with an equilibrium constant K_1.



intermediate

(ii) State the geometry at the Si atom of the intermediate. [1]

trigonal bipyramidal

(iii) In Step 2, the rate determining step, a water molecule coordinates onto the Si intermediate, forming a hexavalent Si complex. In the final step, the hexavalent Si complex decomposes quickly to form the hydrolysis product.

The rate law of step 2 is given by

$$\text{rate} = k_2 [\text{intermediate}] [H_2O]$$

Show clearly that the overall order of reaction is three. [1]

K_1 = [intermediate] / ([Ph_3SiCl] [Nu]), so [intermediate] = K_1 [Ph_3SiCl] [Nu]

The rate of step 2 is the rate since step 2 is rate determining, so rate = k_2K_1 [Ph_3SiCl] [Nu] [H_2O]

Order of reaction with respect to Nu, Ph_3SiCl and H_2O is each 1, so overall order of reaction is 1+1+1=3.

(iv) When different nucleophiles are introduced, the observed rate constant of the reaction, k_{obs}, varies. Table 2.1 contains the observed rate constant for when 3 nucleophiles are present in separate runs.

Nucleophile (Nu)	k_{obs} / $dm^6\ mol^{-2}\ s^{-1}$
HMPA	1200
DMSO	50
DMF	6

Table 2.1

Deduce the relative nucleophilic strength of the three nucleophiles in Table 2.1. [1]

HMPA, DMSO, DMF (strongest to weakest) since the observed rate constant decreases. Stronger nucleophile results in faster rate of reaction and thus higher rate constant.

(v) Suggest how the hydrolysis of Ph_3SiCl can exhibit second-order kinetics with respect to water. [1]

When water acts as Nu (the nucleophile), the rate = k_2K_1 [Ph_3SiCl] $[H_2O]^2$.

(vi) Suggest a balanced equation for the hydrolysis of Ph_3SiCl. [1]

$Ph_3SiCl + H_2O \rightarrow Ph_3SiOH + HCl$

(vii) Suggest a suitable solvent to study the kinetics of this hydrolysis reaction. [1]

CCl_4 (solvent must not be a nucleophile), accept other solvents like dry ether

(viii) Predict and explain how the relative rate of hydrolysis of $MePh_2SiCl$ (Me = CH_3) compares with Ph_3SiCl. [1]

Relative rate of hydrolysis of $MePh_2SiCl$ is faster than Ph_3SiCl because the Ph group is bulkier than the Me group, so the nucleophile experiences more steric hinderance to attach to the Si centre for Ph_3SiCl as compared to $MePh_2SiCl$.

(b) Organotin compounds find good use in radical chemistry. Organic halides may be reduced into an alkane with the use of $^n Bu_3SnH$ ($^n Bu = CH_3CH_3CH_3CH_2$).

The mechanism of the reduction of bromomethane to methane is shown in Table 2.2. An initiator, AIBN, is added in step 1.

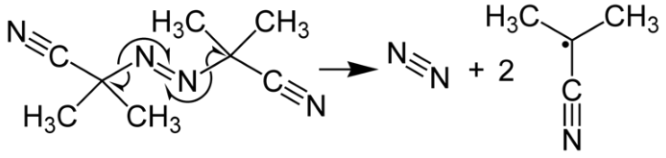
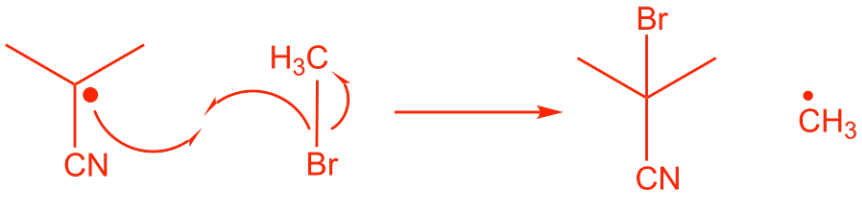
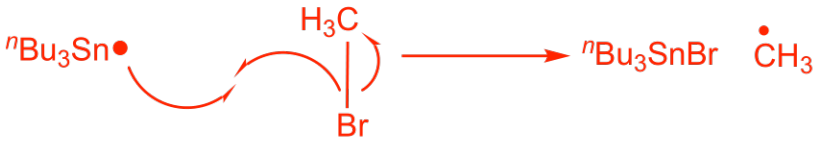
Step 1	
Step 2	
Step 3	$\bullet CH_3 + {}^n Bu_3SnH \rightarrow CH_4 + {}^n Bu_3Sn\bullet$
Step 4	

Table 2.2

Steps 2 to 4 are propagation steps.

(i) Complete Table 7.2 by suggesting balanced equations, with appropriate fish hook arrows, for steps 2 and 4. [3]

(ii) Suggest **two** possible termination steps. [1]

As long as 2 radicals recombine to form 1 molecule, the termination step is possible. Example: $2 \bullet CH_3 \rightarrow C_2H_6$;

(iii) Explain why only a small amount of AIBN is needed for the reaction to proceed. [1]

Steps 2 to 4 will continue to sustain the reaction as it is a chain-reaction that constantly produces the CH_3 and $^n Bu_3Sn$ radical and does not need AIBN to introduce a source of radicals during the reaction.

(c) The valence shell of a Group 14 element has a pair of s electrons and 2 unpaired p electrons.

(i) Explain why the first ionisation energy of the elements in Group 14 generally decreases down the group. [1]

Valence electron is further away from the nucleus down the group as number of principal quantum shells increases, and is hence less tightly bound to the nucleus. Less energy needed to overcome the attraction of the valence electron to the nucleus.

(ii) Fill up Table 2.3 which presents the **cumulative** ionisation energies up to the second and fourth electron of tin and lead. [1]

cumulative ionisation energies up to the	2^{nd} electron	4^{th} electron
Sn	2117 kJ mol^{-1}	8987 kJ mol^{-1}
Pb	2166 kJ mol^{-1}	9326 kJ mol^{-1}

Although Pb is below Sn in Group 14, we notice that the cumulative ionisation energies group increases from Sn to Pb!

Table 2.3

(iii) The cumulative ionisation energies up to the fourth electron for Sn is lower than that of Pb. This difference is more marked when compared to the cumulative ionisation energies up the second electron. This may be explained with the *inert pair effect*, the phenomenon where the pair of s electrons is harder to remove in the later periods.

There are other relevant pieces of data from the *Data Booklet* which provide evidence of the *inert pair effect* in Group 14. These are the standard electrode potentials.

Quote only the relevant electrode potentials and use them to explain how this supports the *inert pair effect* for a Group 14 element. [3]

$E^{\ominus}(Pb^{4+}/Pb^{2+})$ = +1.69 V while $E^{\ominus}(Sn^{4+}/Sn^{2+})$ = +0.15 V (unrelated Sn and Pb couples will be penalised)
More positive $E^{\ominus}$ value for the Pb couple signifies that the 2 6s electrons are much more readily gained for Pb^{4+}, than that of the 5s electrons in Sn^{4+}. Thus, in reverse, it is harder to remove the 2 6s electrons in Pb than that of the 2 5s electrons in Sn.

This supports the inert pair effect for Pb.

[Total: 20]

3 Archaea are microorganisms that can take unusual organic molecules as a source of energy. They are different from bacteria and other single-celled microorganisms.

(a) A nutrient medium containing only carbon-13 isotopically labelled methylamine, $^{13}CH_3NH_2$, in water can be hydrolysed, in the absence of oxygen, as an energy source with the presence of enzymes in certain species of archaea. Some gas was collected as metabolic products at room temperature. This gas contained 2 products in a 1:3 molar ratio. The relative molecular mass of the gas sample was 24.0. The only other non-gaseous product formed is NH_3.

It is known that the enzymatic hydrolysis of methylamine is a redox reaction.

(i) Determine the products of the gaseous mixture, given that there is no nitrogen atoms in the gas collected and both gaseous products contain at least a carbon atom. Identify the gas which was produced in greater amount. [3]

Since 2 gaseous products are formed, and they do not contain nitrogen, we can deduce that methylamine underwent a disproportionation. The oxidation state of C in methylamine is -2.

Suppose that the reduced product was produced in greater amount. If the average oxidation state of carbon in the reduced product decreased by 1 (from -2), then the average oxidation state of carbon in the oxidised product increased by 3. The number of electrons involved in the reduction and oxidation half-equations are the same. See example:

Reduction (R): C(-2) + e^- → C(-3); Oxidation (O): C(-2) → C(+1) + 3 e^-;
Overall: 4 C(-2) → 3 C(-3) + C(+1) [Taking 3 × (R) + (O)]

Reduced product (produced in greater amount)	Oxidised product (produced in smaller amount)	M_r of sample
-3 (C_2H_6, M_r = 42.0)	+1 ($C_2H_2O_2$, M_r = 60.0)	0.75(42.0) + 0.25(60.0) = 46.5
-4 (CH_4, M_r = 17.0)	+4 (CO_2, M_r = 45.0)	0.75(17.0) + 0.25(45.0) = 24.0

Hence, the gaseous products are CH_4, CO_2. Methane is produced in greater amount.
Credit is awarded to showing that CH_4, CO_2 are the products by verifying it with information from the preamble. The candidate may write, without justification, that the products are CH_4, CO_2. However, they must show that the M_r of the sample is indeed 24.0.

(ii) Hence, write a balanced equation for the enzymatic hydrolysis of methylamine. [1]

$4\ CH_3NH_2 + 2\ H_2O \rightarrow CO_2 + 3\ CH_4 + 4\ NH_3$

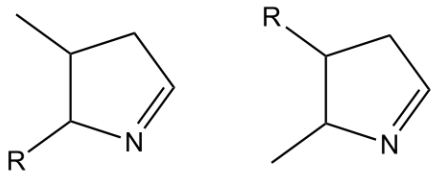
(b) Enzymes involved in methylamine utilisation in archaea contain the residue of an amino acid, **A**. That means that the partial hydrolysis of the enzymes can result in **A** being produced. The molecular formula of **A** is $C_{12}H_{21}N_3O_3$.

Through a series of enzymatic reactions, it is thought that **A** can be biosynthesised from 2 lysine molecules. The systematic name of lysine is 2,6-diaminohexanoic acid.

- Starting from lysine, enzyme 1 isomerises lysine to form **B**. **B** is a constitutional isomer of lysine.
- Amino acid **B** forms a peptide bond with lysine to form dipeptide **C**, catalysed by enzyme 2.
- Enzyme 3 converts **C** to **D**, in a process known as *oxidative deamination*[1]. **D** produces a brick-red precipitate when warmed with Fehling's reagent. The carbon backbones of **C** and **D** are the same.
- An intramolecular reaction results in **D** forming **A**. This is similar to the reaction where **D** produces a positive result with 2,4-DNPH.

Lysine, **A**, **B**, **C** and **D** are α-amino acids. When **A** is hydrolysed, a molecule of lysine is formed as one of its products.

A has a 5-membered ring. Instrumental analysis has narrowed down the carbon backbone of the ring of **A** to either **X** or **Y**. The R group is to be determined.



X **Y**

You may find this additional information useful in solving the question.

When 2 amino acids form a dipeptide, a new C—N bond is formed. This is known as a peptide bond. Fig 3.1 shows an example. The new C—N bond is in bold.

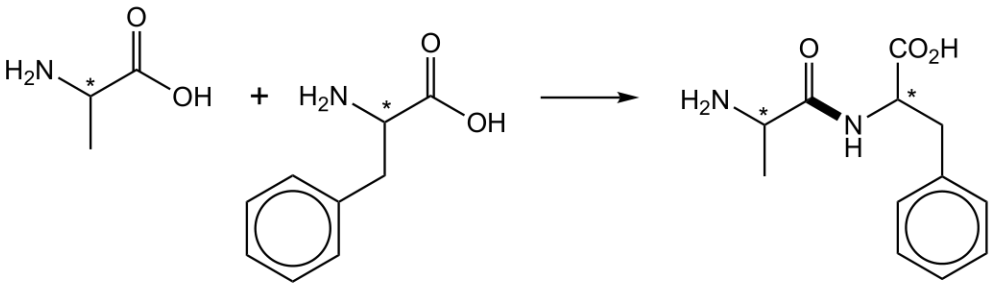


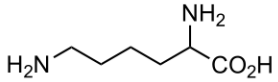
Fig 3.1

The asterisks (*) mark the α carbon of the two α-amino acids.

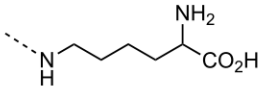
[1]*Deamination* is a reaction where a molecule loses an amine group.

(i) Deduce the structure of the R group. [2]

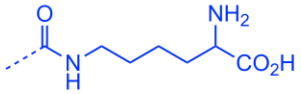
When **A** is hydrolysed, lysine will be one of its products. Lysine has the structure below.



Since **A** is an α-amino acid, the amine group at the 6 position must be used to form a peptide bond. Hence, the R group must contain:

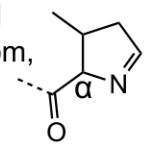


There are a total of 5 Cs, 1 N and 8 Hs in the structures of **X** and **Y**, and for the lysine side of the molecule, 6 Cs, 2 Ns, 2 Os and 13 Hs. Hence, we need to assign 1 more C and O each to the R group. Since a peptide bond is formed, this C and O is the part of the peptide bond, so the R group is

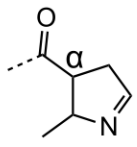


(ii) Determine whether **A** has the carbon backbone of **X** or **Y**. You may find it useful to identify the α carbons in **A** first. [1]

Noting that the α carbon is next to the C on the C=O peptide link, the supposed α carbons are labelled as such. However, this α carbon must be next to a N atom, since **A** was formed from 2 α-amino acids. Hence, **A** has the carbon backbone of **X**. (The example of the formation of a dipeptide is given to help you identify the characteristics of the α carbon—what it should be adjacent to.)



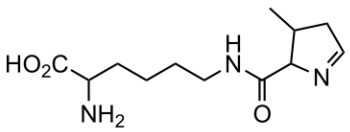
X



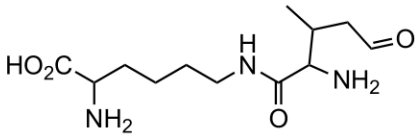
Y

(iii) Deduce the structures of **B**, **C** and **D**. For each reaction in the bullet points, state the type of reaction described and the functional group involved. [5]

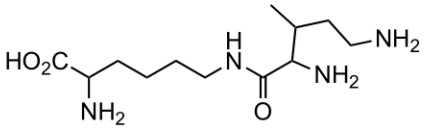
A is



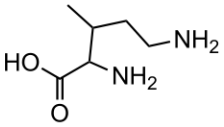
Since **D** undergoes a condensation reaction with 2,4-DNPH, **D** undergoes an similar intramolecular condensation reaction to form **A**. Furthermore, **D** undergoes oxidation with Fehling's reagent. Hence, **D** must have an aldehyde and an amine reacting in a similar fashion. **D** is



Noting that **C** undergoes an *oxidative deamination*, **C** had lost an amine functional group, and **C** was oxidised. However, the carbon backbone did not change, meaning that the aldehyde group most likely replaced the amine group. Furthermore, **C** is a dipeptide of **B** and lysine. Since **B** is a constitutional isomer of lysine, and that from **C** to **D** the carbon backbone did not change, this leaves us to place the "missing" amine group at the end of **C**. Hence, **C** is



Breaking the peptide bond in **C** yields lysine and **B**. **B** is



The cell membrane of archaea is composed of a lipid bilayer similar to bacteria. However, there are a few structural differences in the lipids found in cell membranes. Table 3.2 shows the structural formula of the lipids.

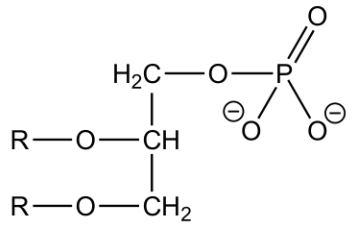
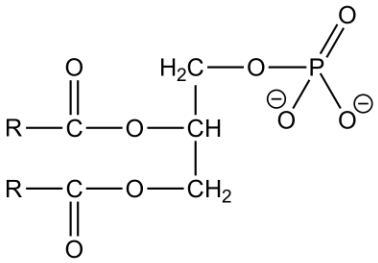
 Structure of the lipids found in archaea	 Structure of the lipids found in bacteria

Table 3.2

In part **(c)**, the R group is a long hydrocarbon chain, and differs between species of archaea and bacteria. The R group in **(b)** is not to be considered in subsequent parts.

(c) **(i)** From Table 3.2, state **one** difference between the structure of the lipids found in archaea and bacteria. [1]

The archaea lipid contains ethers, while the bacteria lipid contains esters.

……

The lipid bilayer may act as a “liquid” or “solid” depending on the temperature. At the phase transition temperature, the lipid bilayer may transition from the “liquid” to the “solid” phase (or *vice versa*). The phase transition temperature is attributed to the strength of the interactions between the R groups.

(ii) State the predominant interactions between the R groups of the lipids and explain how they arise. [2]

Dispersion forces / instantaneous dipole-induced dipole interactions

At a certain point in time, the electron density of the R group may be uneven, where it is richer on one side and poorer on the other. This creates an instantaneous dipole. This instantaneous dipole will induce another dipole on a neighbouring R group. The electrostatic attraction between these fluctuating dipoles results in instantaneous dipole – induced dipole interactions.

(iii) The R groups found in archaea are typically branched and contain rings. However, the R groups found in bacteria are typically straight chain hydrocarbons.

Suggest why the phase transition temperature of archaea is generally lower than that of bacteria. [1]

Less surface area for electron cloud to be polarised leads to poorer polarisation of the electron cloud of the R groups. This leads to weaker dispersion forces between R groups, so less energy is needed to overcome these weaker dispersion forces.

(iv) The presence of unsaturation in the R group affects the phase transition temperature due to the disruption of packing between individual lipid molecules. This may be attributed to "kinks" in the R group. "Kinks" are inflexible bends in the R group.

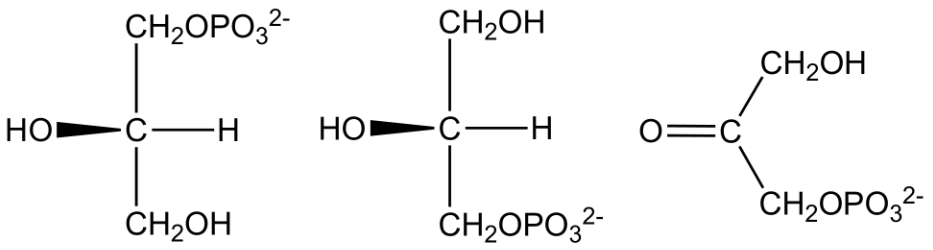
Explain why "kinks" are inflexible. [1]

There is restricted rotation about the C=C bond.

(v) Suggest another characteristic of the R group, other than that discussed in **(iii)** and **(iv)**, that will affect the phase transition temperature of the lipid bilayer in both and bacteria and explain your answer. [2]

Length of carbon chain / number of carbon atoms.
More carbon atoms leads to more electrons and a more polarisable electron cloud, creating stronger dispersion forces between R groups. Thus, more energy is needed to overcome the dispersion forces between R groups, leading to a higher phase transition temperature when there are more carbon atoms.
The answer should state what criteria would result in a higher/lower phase transition temperature.

(d) Lipids have a glycerol backbone and are biosynthesised from a glycerol phosphate precursor. In bacteria, the template glycerol phosphate is sn-G-3-P while the template glycerol phosphate is sn-G-1-P for archaea. Both sn-G-3-P and sn-G-1-P come from dihydroxyacetone phosphate (DAP). The structures of sn-G-3-P, sn-G-1-P and DAP are shown below.



sn-G-1-P sn-G-3-P DAP

(i) DAP is reduced by NADH to form sn-G-3-P or sn-G-1-P depending on reaction conditions. The oxidised form of NADH is NAD^+.

Standard reduction potentials are quoted in Table 3.3.

Couple	Half-equation	$E^\ominus$ / mV
DAP / sn-G-3-P	**DAP + $2e^-$ + $2H^+$ ⇌ sn-G-3-P**	−190
NAD^+ / NADH	$NAD^+ + H^+ + 2e^- \rightleftharpoons NADH$	−320

Table 3.3

Complete the half equation for the reduction of DAP to sn-G-3-P. [1]

You may use the abbreviations DAP and sn-G-3-P.

(ii) Show that the reduction of DAP to sn-G-3-P by NADH is spontaneous, and calculate $\Delta G^\ominus$ of the process per mole of DAP reduced to sn-G-3-P. [2]

$E^\ominus = E^\ominus(\text{DAP/sn-G-3-P}) - E^\ominus(NAD^+/NADH) = -190 - (-320) = +130$ mV
which is positive. Hence reduction is spontaneous.

$$\Delta G^\ominus = -2(96500)(130\times10^{-3}) = -25090 \text{ J mol}^{-1}$$

(iii) Explain how the presence of enzymes that catalyse the reaction affects the standard cell potential of the reduction of DAP by NADH. [1]

The standard cell potential remains the same / is unaffected, as the enzyme does not change any thermodynamic property of the reaction / does not change K_c / does not change $\Delta G^\ominus$.

(iv) Compare $E^\ominus$(DAP / sn-G-1-P) with $E^\ominus$(DAP / sn-G-3-P). Explain your answer. [1]

They are the same. sn-G-1-P and sn-G-3-P are enantiomers, so they have the same physical properties, that includes their Gibbs' Free Energy of formation.

Reject arguments stating that sn-G-1-P and sn-G-3-P are the same molecules.

(v) A hydroxyl (—OH containing) organic compound that has a long hydrocarbon chain, together with sn-G-1-P or sn-G-3-P, are combined to form the lipid bilayer in bacteria and archaea. This process is facilitated by enzymes which catalyse the biosynthesis of the lipid bilayer.

The stereochemical configuration of the template glycerol phosphate is retained.

Fig 3.4 illustrates an example for the biosynthesis of the lipid bilayer for archaea.

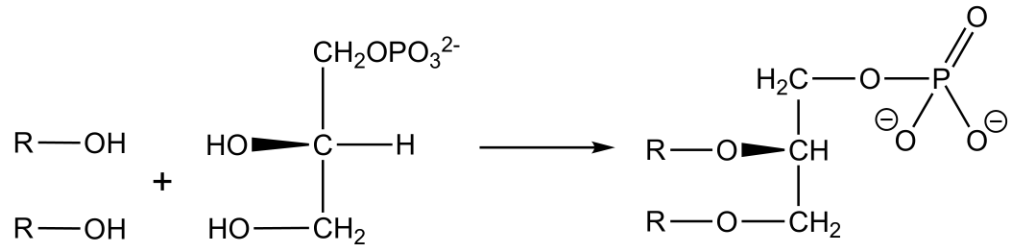
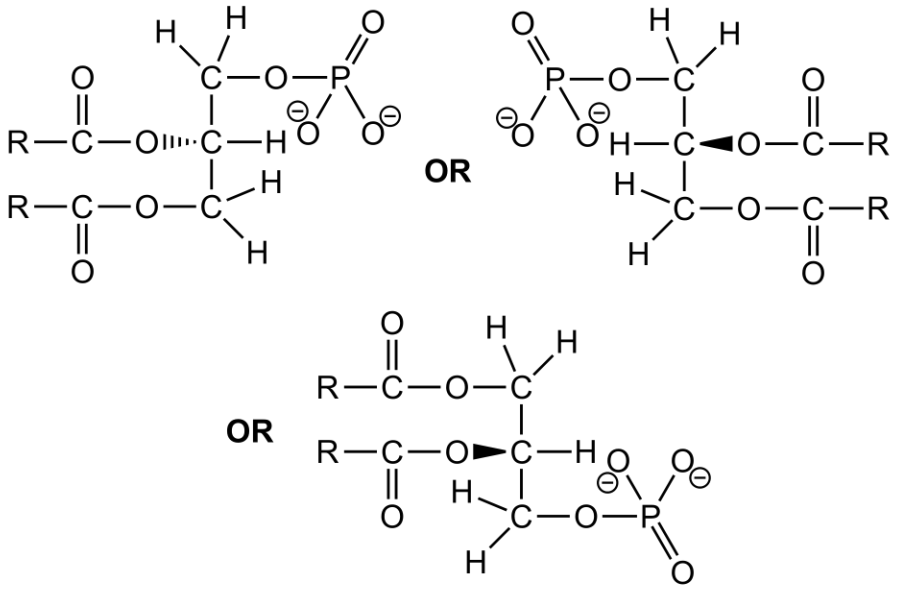


Fig 3.4

Using the information above, redraw the **displayed formula** of the lipid bilayer for bacteria. You must indicate stereochemical information where relevant. [1]

Your answer should retain the same functional groups as shown in Table 3.2.



They are the same molecules, drawn differently.

[Total: 25]