Advanced Subsidiary GCE Subject Chemistry B (Salters)

Unit F335: Chemistry by Design - High banded Candidate style answer

Introduction

OCR has produced these candidate style answers to support teachers in interpreting the assessment criteria for the new GCE specifications and to bridge the gap between new specification release and availability of exemplar candidate work.

This content has been produced by senior OCR examiners, with the input of Chairs of Examiners, to illustrate how the sample assessment questions might be answered and provide some commentary on what factors contribute to an overall grading. The candidate style answers are not written in a way that is intended to replicate student work but to demonstrate what a "good" or "excellent" response might include, supported by examiner commentary and conclusions.

As these responses have not been through full moderation and do not replicate student work, they have not been graded and are instead, banded "medium" or "high" to give an indication of the level of each response.

Please note that this resource is provided for advice and guidance only and does not in any way constitute an indication of grade boundaries or endorsed answers.

1 Hydrogen is used to make ammonia, an important agricultural chemical.

$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$ ***equation 1.1***

Ammonia is used to make fertilisers.

(a)(i) Suggest the cheapest source for the nitrogen gas used in *equation 1.1.* **[1]**

Candidate style answer	*Examiner's commentary*
the atmosphere	This candidate has made a good start. 'Air' is a better answer than 'atmosphere' for part **(i)** but the latter is allowed.

(ii) Ammonium nitrate, NH_4NO_3, is a fertiliser made from ammonia. **[2]**
Calculate the percentage by mass of nitrogen in NH_4NO_3.

Candidate style answer	*Examiner's commentary*
28 x 100/80 = 35%	The calculation is correct

(iii) Ammonium sulfate is another fertiliser.
Write the formula of ammonium sulfate. **[1]**

Candidate style answer	*Examiner's commentary*
(NH4)2SO4	The formula in part **(iii)** is correct (learn those charges on ions!).

(iv) Explain <u>one</u> advantage and <u>one</u> disadvantage of adding ammonium salts to the soil. [2]

Candidate style answer	*Examiner's commentary*
advantage: they feed the soil disadvantage: they get washed into rivers causing eutrophication	In part **(iv)**, the first answer is just too vague to score; something along the lines of providing nutrients for plants was required. The disadvantage is much more focused and is scores the mark.

(b) Hydrogen is produced industrially from methane by steam reforming as shown below.

$CH_4(g) + H_2O(g) \rightleftharpoons CO(g) + 3H_2(g)$ ***equation 1.2***

(i) Write an expression for Kc for the reaction in *equation 1.2.* [2]

Candidate style answer	*Examiner's commentary*
Kc = [CO][H2]3 / [CH4] [H2O]	Correct answer.

(ii) At the temperature of the reaction, Kp = 292 mol2 dm–6. The concentrations of some of the gases present in an equilibrium mixture at this temperature were measured and are given in the table.

gas	concentration/ mol dm–3
CH4	5.00
H2O	5.00
H2	12.0

Calculate the concentration of carbon monoxide under these conditions.
Give your answer to a <u>suitable</u> number of significant figures. [3]

Candidate style answer	*Examiner's commentary*
[CO] = Kc [CH4] [H2O]/ [H2]3 = 292 x 5 x 5/ 123 = 4.2 mol dm-3	The statement of K_c and the calculation are fine, though the candidate will lose the significant figure mark. The data is all quoted to three significant figures, so that is the number to which the answer should be given: 4.22.

(c)(i) Use le Chatelier's principle to predict the effect of <u>decreasing</u> the pressure on the yield of hydrogen in *equation 1.2* [3]

Candidate style answer	*Examiner's commentary*
There are more moles on the right hand side of the equation than the left. Decreasing the pressure will mean more hydrogen.	In part **(i)**, the candidate clearly understands what is going on but has not been careful enough in expressing it. There are three marks here which should have given a clue. The missing step is that the equilibrium position will move to the right.

(ii) Suggest a reason why a pressure of around 30 atm is actually used for the process. [1]

Candidate style answer	*Examiner's commentary*
To increase the rate without losing too much yield.	The reference to Le Chatelier's principle is also a clue that equilibrium position should be mentioned. Part **(ii)** is correct.

$CH_4(g) + H_2O(g) \rightleftharpoons CO(g) + 3H_2(g)$ *equation 1.2*

(d) The mixture of gases from the reaction in *equation 1.2* is mixed with more steam and passed over a hot iron catalyst. The carbon monoxide is converted to carbon dioxide.

(i) Write an equation for the reaction of carbon monoxide with steam. [1]

Candidate style answer	*Examiner's commentary*
CO + H2O → CO2 + H2	The equation is correct.

(ii) Suggest <u>two</u> reasons why the carbon monoxide is <u>not</u> released into the atmosphere. [2]

Candidate style answer	*Examiner's commentary*
It is harmful and it can be used as a fuel	In part **(ii)**, 'harmful' is not enough. 'Harmful to life' would just have done, though 'toxic' is better. The second point is fine.

(e)(i) Predict the sign of ΔSsys for the forward reaction in *equation 1.2*. Explain your reasoning. [1]

Candidate style answer	*Examiner's commentary*
Positive, since there are more molecules on the right	

(ii) Use the entropy data given in the table below to calculate the value of ΔSsys (with the correct <u>sign</u>) for the forward reaction in *equation 1.2*. [3]

compound	S / J K–1 mol–1
CH4(g)	+186
H2O(g)	+189
CO(g)	+198
H2(g)	+131

Candidate style answer	*Examiner's commentary*
393 + 198 – 189 – 186 = +216 J K–1mol–1	

(iii) At 500 K the value of ΔStot for the forward reaction is –1784.
Calculate the value of ΔStot at 1000 K.
Assume that ΔSsys does not change with temperature. [2]

Candidate style answer	*Examiner's commentary*
−1784 = +216 − ΔH/500 , thus ΔH = +1 x 106 J mol−1 ΔS = +216 − 1 x 106 /1000 = −784 J K−1 mol−1	The candidate has shown definite ability by getting part **(i)** correct and steering through these tricky calculations correctly.

2 The pigment chrome yellow consists of lead chromate(VI), PbCrO4. It is made by precipitation when solutions of lead nitrate and sodium chromate(VI) are mixed.

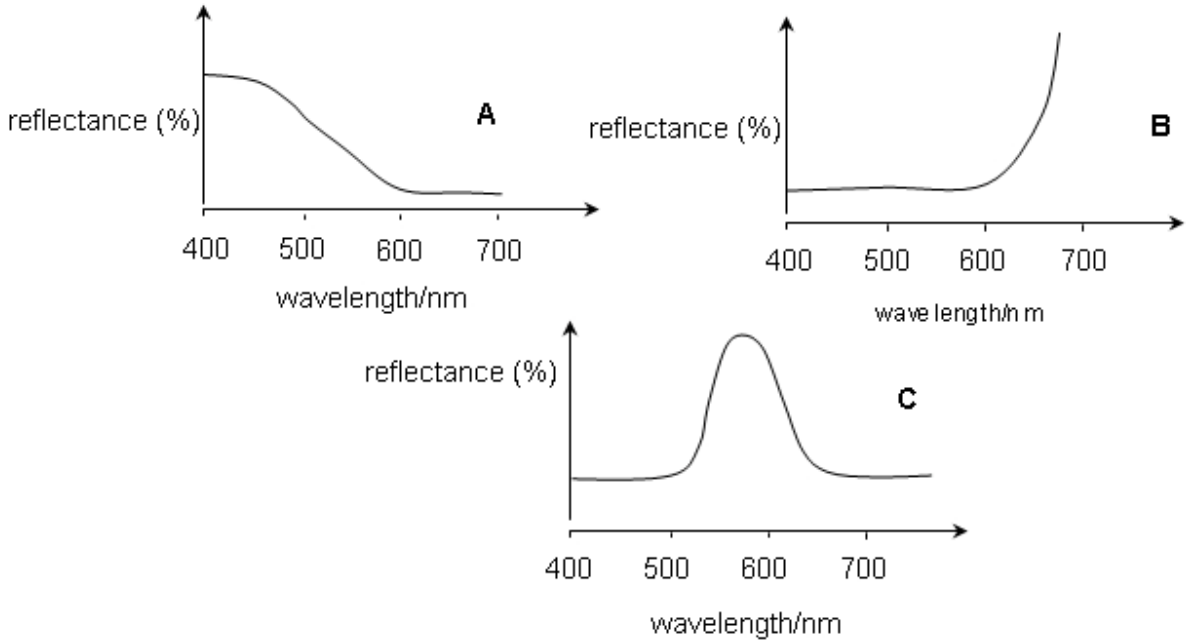
(a) Explain why (VI) is used to describe the CrO42– ion. [1]

Candidate style answer	*Examiner's commentary*
It is the oxidation state	No, not good enough; the answer must say it is the oxidation state of the chromium. Presumably the candidate knew this, so why wasn't it said?

(b) Write an <u>ionic</u> equation for the precipitation of lead chromate(VI), showing state symbols. [2]

Candidate style answer	*Examiner's commentary*
Pb(NO3)2(aq) + Na2CrO4(aq) → PbCrO4(s) + 2NaNO3(aq)	This is an occasion where correct chemistry does not score full marks as it does not answer the question. This is a full equation where an ionic equation was asked for. Fortunately for the candidate, the mark-scheme allows the state symbol mark to be awarded in this case, so one mark is scored.

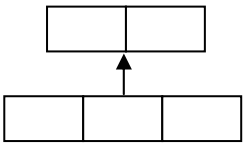
(c) Pigments can be identified by their visible reflectance spectra.
The spectra of three pigments are shown below, lettered A, B and C.



State, with a reason, which is the reflectance spectrum of chrome yellow. **[2]**

Candidate style answer	*Examiner's commentary*
`C because it reflects yellow`	Yes, this is enough to score both marks.

(d) The diagram below helps to explain the yellow colour of the chromate ion.



(i) Which electron sub-shell is shown in the diagram? [1]

Candidate style answer	*Examiner's commentary*
d	This is not enough for part **(i)**. 3d was required.

(ii) What causes the splitting of the orbitals within the sub-shell? [1]

Candidate style answer	*Examiner's commentary*
the effect of the ligands	The answer to **(ii)** is correct.

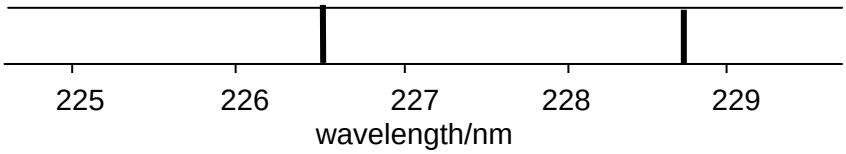
(e) A painting is being analysed. Four yellow pigments it might contain are shown below.

- **barium yellow, $BaCrO_4$;**
- **cadmium yellow, CdS;**
- **orpiment, As_2S_3;**
- **yellow ochre, containing Fe_2O_3.**

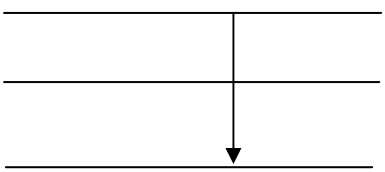
(i) Give the systematic name of the compound contained in yellow ochre. [1]

Candidate style answer	*Examiner's commentary*
iron(III) oxide	Part **(i)** is correct;

(ii) One method of identifying pigments is to use atomic emission spectroscopy.
Part of a simplified atomic emission spectrum of the pigment is shown below.



Explain why the emissions occur at specific frequencies.
Include a diagram in your answer.
In your answer, you should make clear how the observed effect depends on the explanation. [4]

Candidate style answer	*Examiner's commentary*
 electron falling emits light E=hv	In part **(ii)** a mark is scored for the diagram and a mark for E=hv. However, the vital words 'electron energy levels' have been omitted. This loses the mark for the lack of a label on the diagram. Also the 'electron falling emits light' does not score, as, to 'link the observed effect to the explanation', the electrons had to be said to be falling through energy levels. When the pencil icon is shown for 'quality of written communication' it is important that care is taken over the logic of the answer to score maximum marks.

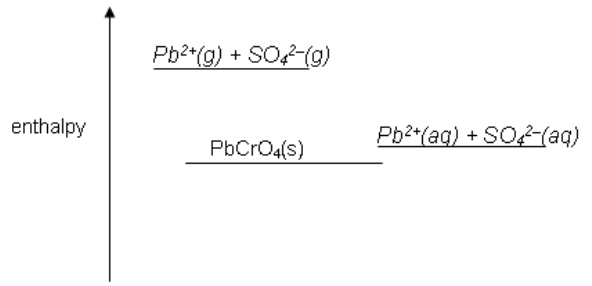
(iii) Use the data in the table below to identify the element and hence the <u>systematic name</u> of the pigment. [2]

element	certain characteristic emissions/nm
Ba	233.5
Cd	228.8 226.5
As	228.8 235.0
Fe	238.2 239.7

Candidate style answer	*Examiner's commentary*
`cadmium  cadmium sulfide`	Part **(iii)** scores both marks according to the mark scheme, though, strictly speaking it should be 'cadmium(II) sulfide'.

(f) Lead chromate(VI) is insoluble because it has an enthalpy change of solution of +17 kJ mol–1. An estimate of the lattice enthalpy of lead chromate is –1000 kJ mol–1 .

(i) Complete the diagram to illustrate this by drawing and labelling suitable enthalpy levels and inserting the given values. [3]

Candidate style answer	*Examiner's commentary*
	These are good answers except for one (careless) omission of the numbers on the energy level diagram.

(ii) Use your diagram to calculate the sum of the enthalpy changes of hydration of the lead and chromate ions. [1]

Candidate style answer	*Examiner's commentary*
`−983 kJ mol−1`	The calculation shows that the numbers were understood.

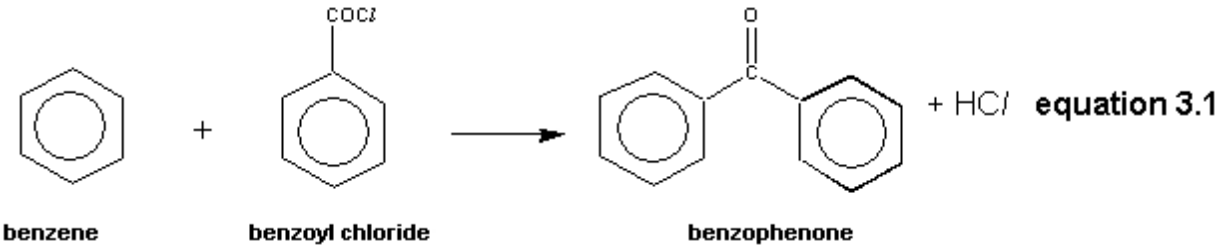
(iii) Name the bonds and intermolecular bonds that would be made and broken if lead chromate were to dissolve.

Explain, in terms of bonds broken and made, the endothermic nature of this dissolving process.

In your answer, you should use appropriate technical terms, spelt correctly. [4]

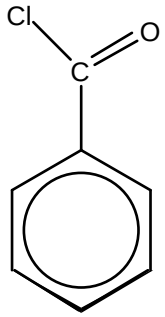
Candidate style answer	*Examiner's commentary*
The bonds broken are electrostatic forces between the ions in lead chromate solid and some hydrogen bonds between water molecules. The bonds formed are ion-dipole bonds between the lead and chromate ions and water. In this case, the bonds broken are slightly stronger than the bonds made.	Part (iii) scores full marks, though it might have been better to describe the bonds in the lattice as 'ionic'. 'Electrostatic' is acceptable, however.

3 The compound benzophenone is used in cosmetics and as a sunscreen. It can be prepared in the laboratory by the following reaction in the presence of an aluminium chloride catalyst.



equation 3.1

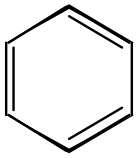
(a)(i) Draw the <u>full structural formula</u> for the acyl chloride group in <u>benzoyl chloride</u>. [1]

Candidate style answer	*Examiner's commentary*
	Again the candidate has not read the question here. Just the –COCl part was required as a full structural formula. However, the candidate's answer would score the mark in part **(i)**.

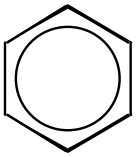
(ii) Name the <u>reaction mechanism</u> by which benzene reacts in *equation 3.1*. [2]

Candidate style answer	*Examiner's commentary*
electrophilic substitution	Part **(ii)** is correct.

(b) An alternative way of representing the structure of <u>benzene</u> is shown as <u>representation 1</u> below.



representation 1



representation 2

Give reasons why <u>representation 2</u> is sometimes preferred. Give <u>one</u> reason in terms of the shape of the molecule and <u>one</u> reason in terms of its chemical properties. [2]

Candidate style answer	*Examiner's commentary*
shape: it would not be a regular hexagon since double and singe bonds are of different lengths chemical properties: it would react with bromine water to decolorise it	The candidate has been careless here and not answered the question. Unless it is clear, answers beginning 'it' would be interpreted as referring to representation 2, since this follows from the phrasing of the question. The candidate would score for the shape, because the reference to double and single bonds makes it clear which representation is being referred to. No marks would be scored for the properties as this is not clear. The best rule is never to start answers with 'it', always say what you are talking about.

(c) Sunscreens absorb ultraviolet radiation.

Explain, in terms of electronic energy levels, why a substance such as benzophenone absorbs in the ultraviolet but is not coloured.

In your answer, you should make it clear how your explanation links with what is observed. [5]

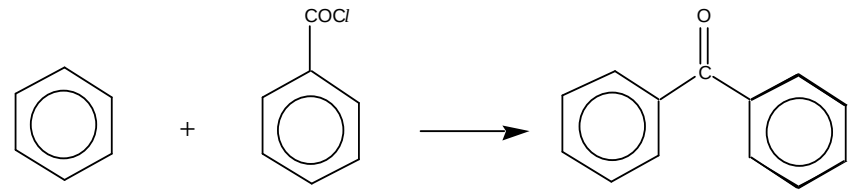
Candidate style answer	*Examiner's commentary*
It has delocalisation but not much so the gap between energy levels is big. Since $\Delta E=hv$, the frequency absorbed when electrons are excited from one energy level to another is in the uv, not the visible (visible frequencies are smaller than uv ones)	This is a good answer, even though it starts with 'it'. It does not, however, answer the second part of the question: why benzophenone is not coloured. For this it would need to say 'coloured substances absorb in the visible' which the candidate probably knows but has not written down.

(d) The most effective way of removing the aluminium chloride at the end of the reaction is to hydrolyse it with water and to run it to waste.

$AlCl_3(s) + 3H_2O(l) \rightarrow Al(OH)_3(s) + 3HCl(aq)$

In the 1980s, benzophenone was made industrially by this method. Suggest and explain <u>two</u> reasons why this could lead to environmental hazards. [4]

Candidate style answer	*Examiner's commentary*
aluminium salts would enter the waste system and possibly reach drinking water. HCl is strongly acidic and polluting	The candidate has selected two correct pollutants and thus scores some marks. However, the reasons are not sufficient to score as they are vague. 'Toxic" would have scored in both the selected cases.



benzene **benzoyl chloride** **benzophenone** **+ HCl** ***equation 3.1***

(e) More recently, another metal catalyst has been used and a solvent that is an ionic liquid. A very high percentage yield is achieved and the catalyst and the solvent can be recycled.

(i) Explain the meaning of the term ionic liquid. [1]

Candidate style answer	*Examiner's commentary*
an ionic substance that is a liquid at room temperature	Correct answer.

(ii) If the percentage yield were 100%, calculate the maximum mass of benzophenone that could be produced from 10 kg of <u>benzene</u>. [2]

Candidate style answer	*Examiner's commentary*
182 x 10/78 = 23kg	Correct answer.

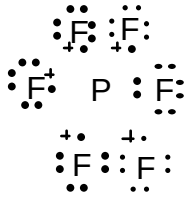
(iii) Calculate the atom economy of the reaction in *equation 3.1*. [3]

Candidate style answer	*Examiner's commentary*
182 x 100/218.5 = 83%	The calculations are correct

(iv) Explain the importance to society and the environment of using the modern method of making benzophenone. [4]

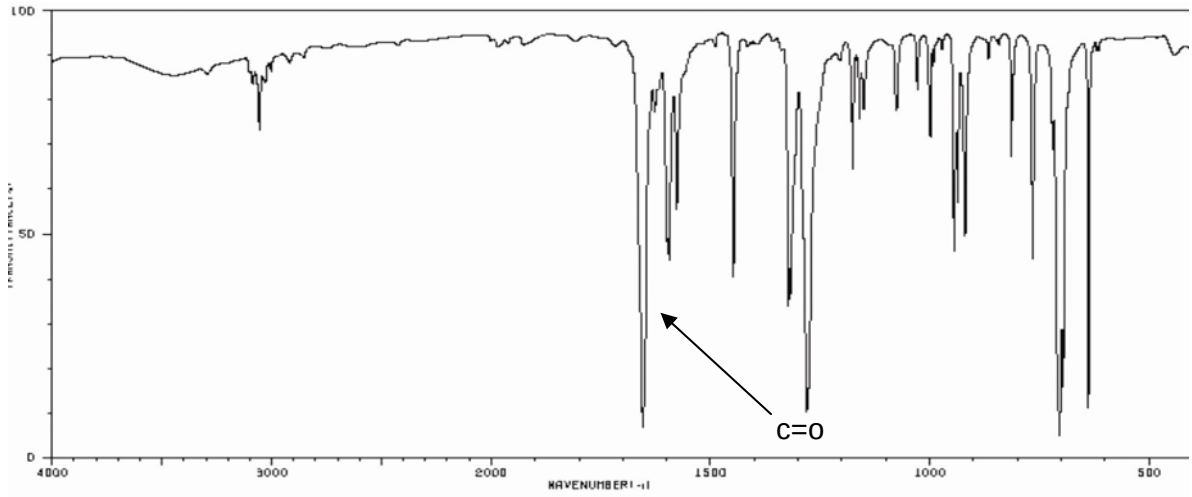
Candidate style answer	*Examiner's commentary*
the catalyst is non-polluting as it can be recycled. The reaction has a high atom economy and percentage yield.	There are four good points made in part **(iv)**.

(v) The ionic liquid contains the PF6– ion. Draw a 'dot-and-cross' diagram for this ion and give a word that describes its shape. [3]



Candidate style answer	*Examiner's commentary*
`hexahedral`	The diagram in part **(v)** is acceptable for two marks. It is just the description of the shape that is wrong. The shape is octahedral as an octahedron has six points.

(f) A chemist wished to confirm the identity of a sample of benzophenone by recording its infrared and proton NMR spectra. The infrared spectrum is shown below.



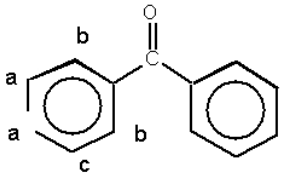
SDBSWeb : http://www.aist.go.jp/RIODB/SDBS/ (National Institute of Advanced Industrial Science and Technology, 13/11/06)

(i) Use the Data Sheet to select one absorption in the spectrum that is characteristic of benzophenone. Label this absorption with the bond that causes it. [1]

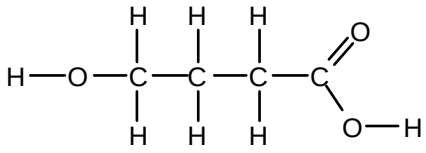
Candidate style answer	*Examiner's commentary*
`See diagram`	The bond indicated in part **(i)** is quite correct.

(ii) The proton NMR spectrum of benzophenone contains three signals in the ratio 2 : 2 : 1.

Mark on the structure below all the protons in each environment, lettering the environments a, b and c. **[2]**

Candidate style answer	*Examiner's commentary*
 **benzophenone**	In part **(ii)**, the candidate has omitted to mark a,b,c on the equivalent stoms on the other ring, so only one of the two marks is scored.

4 The substance GHB was originally designed for use in sleeping pills. However, other drug-related uses were found for the substance and its sale was restricted in 2003. GHB stands for gamma-hydroxybutyric acid, an old name for the structure shown below.



GHB

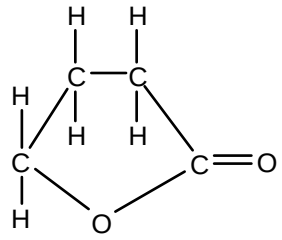
(a)(i) Name the <u>two</u> functional groups in GHB. **[2]**

Candidate style answer	*Examiner's commentary*
`alcohol; carboxylic acid`	Correct answer.

(ii) Give the systematic name for GHB. **[2]**

Candidate style answer	*Examiner's commentary*
`3-hydroxybutanoic acid`	The functional groups are correct, however the name is not. Numbering on the butanoic acid starts on the carboxyl carbon, so this is 4-hydroxybutanoic acid. One mark is scored for the name, however.

(b) A substance known as GBL is converted into GHB in the body. Its structure is shown below.



GBL

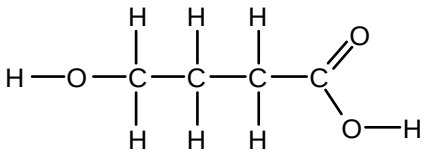
(i) Name the functional group in GBL. [1]

Candidate style answer	*Examiner's commentary*
`ester`	Correct answer.

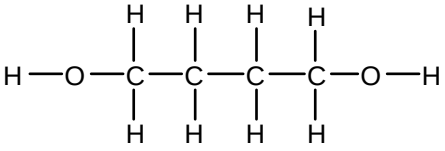
(ii) Name the <u>type</u> of reaction by which GBL forms GHB in the body. [1]

Candidate style answer	*Examiner's commentary*
`hydrolysis`	Correct answer.

(c) A molecule that has the same effect on the body as GHB is called 'GHB alcohol'. Its structure is shown below, together with the structure of GHB.

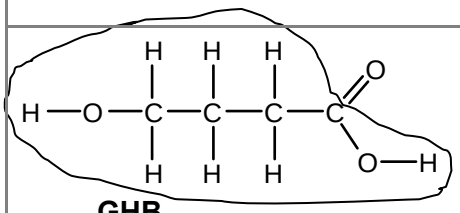
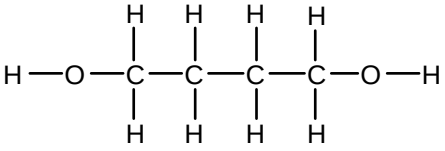


GHB



GHB alcohol

(i) On the molecule of GHB above, draw a ring round the largest part of the molecule that could be the pharmacophore. [1]

Candidate style answer	*Examiner's commentary*
 **GHB**  **GHB alcohol**	One mark for the pharmacophore.

(ii) Suggest why both of these molecules are able to bind to the same receptor site in the body. Name the intermolecular bonds involved. [3]

Candidate style answer	*Examiner's commentary*
`They have the same shape and thus will hydrogen bond with the receptor`	The answer to part **(ii)** lacks detail. There are three marks, so presumably three points to make. The missed point is mentioning that the –OH groups are the ones that hydrogen bond.

(d) Chemists are constantly seeking new medicines, starting from known pharmacophores.

(i) Name a modern technique that allows chemists to view the possible ways in which a molecule can bind on to a receptor site. [1]

Candidate style answer	*Examiner's commentary*
computer modelling	Correct answer.

(ii) Suggest how chemists might justify continuing to manufacture GHB when it has been implicated as a "date-rape" drug. 2]

Candidate style answer	*Examiner's commentary*
if it had an important application for which no other drug was suitable if suitable precautions were taken to control its use	Good answer.

(e) GHB is a weak acid. Weak acids can be represented as HA.

(i) Write an equation to show how a weak acid HA behaves when dissolved in water. 1]

Candidate style answer	*Examiner's commentary*
HA $\rightleftharpoons$ H+ + A−	Part **(i)** is correct.

(ii) Use ions and molecules from this equation to explain the meaning of the term conjugate base. [2]

Candidate style answer	*Examiner's commentary*
HA is the conjgate acid of A−	Part **(ii)** is incomplete and would score only one of the two marks; to gain the second it is necessary to mention proton loss.

(iii) Write an expression for the acidity constant Ka of an acid HA. 1]

Candidate style answer	*Examiner's commentary*
Ka = [H+] [A−] / [HA]	Part **(iii)** is correct.

(iv) A 0.10 mol dm–3 solution of GHB has a pH of 2.9. [4]
Calculate the value of Ka for GHB and give its units.

Candidate style answer	*Examiner's commentary*
1.59 x 10−5 mol dm−3	Part **(iv)** is also correct. It is, however, most unwise not to show working as a wrong answer with no working scores zero, whereas examiners look for 'error carried forward' if working is present.

(v) State one simplifying assumption that you made when carrying out your calculation in (iii). [1]

Candidate style answer	*Examiner's commentary*
GHB is a weak acid	In part **(v)**, the candidate has restated part of the question. The approximations expected are either that $[H^+] = [A^-]$ (i.e. the ionisation of the water has been ignored) or that the equilibrium concentration [HA] is the same as the initial concentration.

(f) A mixture of GHB and its sodium salt acts as a buffer solution.

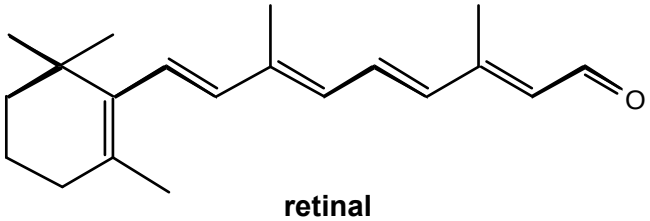
(i) Explain the meaning of the term buffer solution and explain why buffer solutions are found in our bodies. [5]

Candidate style answer	*Examiner's commentary*
Buffer solutions do not change much in pH when acid or alkali is added. They are found in our bodies because enzymes only work at narrow pH ranges and buffers keep their environment within these ranges.	This is a good answer to part **(i)** but it omits one thing. No buffer can withstand vast amounts of acid or alkali, so the answer should have specified 'small amounts' of these.

(ii) Calculate the pH of a buffer solution containing equal amounts of GHB and its sodium salt. [2]

Candidate style answer	*Examiner's commentary*
pH = − log(1.59 x 10−5) = 4.8	The answer to **(ii)** is correct and shows a bit more working this time.

5 The rod cells in the retina at the back of the eye contain an alcohol called retinol which is responsible for their sensitivity to light. Retinol is oxidised by an enzyme-catalysed reaction to the aldehyde retinal.

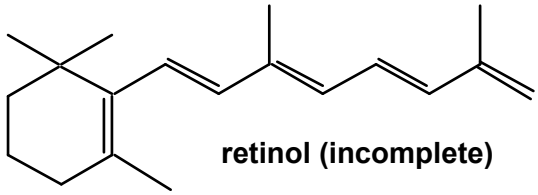


retinal

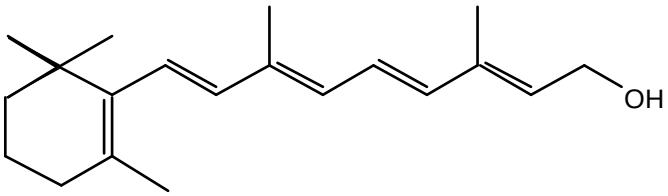
(a)(i) Deduce the molecular formula of retinal from its skeletal formula above. [1]

Candidate style answer	*Examiner's commentary*
C20H26O	Part **(i)** is incorrect, there are 28 not 26 hydrogens. It is a good idea to mark the hydrogen atoms on the skeletal formula as you count them up.

(ii) Suggest the structure of the alcohol <u>retinol</u> by completing the skeletal formula below. [2]



retinol (incomplete)

Candidate style answer	*Examiner's commentary*
	

(iii) Name a functional group which is present in <u>both</u> retinol and retinal. [1]

Candidate style answer	*Examiner's commentary*
`alkene`	Parts **(ii)** and **(iii)** are completely correct.

(b)(i) What reagents and conditions could be used to convert an alcohol to an aldehyde <u>in a laboratory</u>? [3]

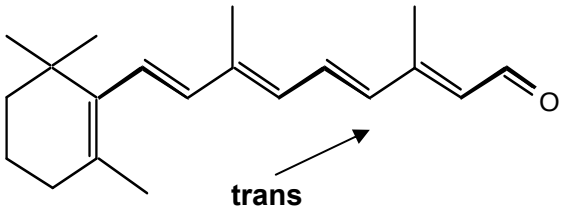
Candidate style answer	*Examiner's commentary*
`reflux with potassium dichromate`	The candidate scores a mark for potassium dichromate. This needs to be acidified (second mark) and the mixture should be distilled (not refluxed) to get the aldehyde (rather than the carboxylic acid) for the third mark.

(ii) How many moles of hydrogen molecules would you expect to react with one mole of <u>retinol</u>? [1]

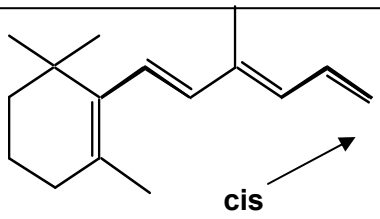
Candidate style answer	*Examiner's commentary*
`5`	5 is correct in part **(ii)**.

(c) When light shines on the rod cells an enzyme-catalysed reaction occurs. This changes the arrangement around the double bond from *trans* to *cis*, as indicated in the structure below.

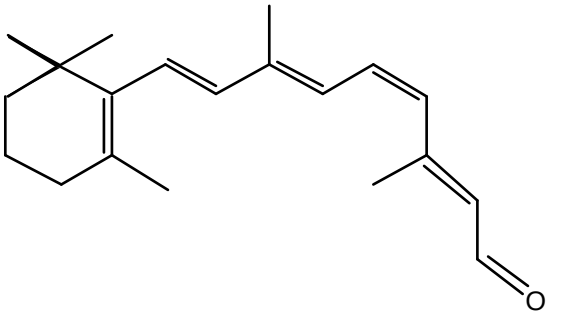
(i) Suggest the structure of *cis*–retinal by completing the skeletal formula below. [2]



retinal



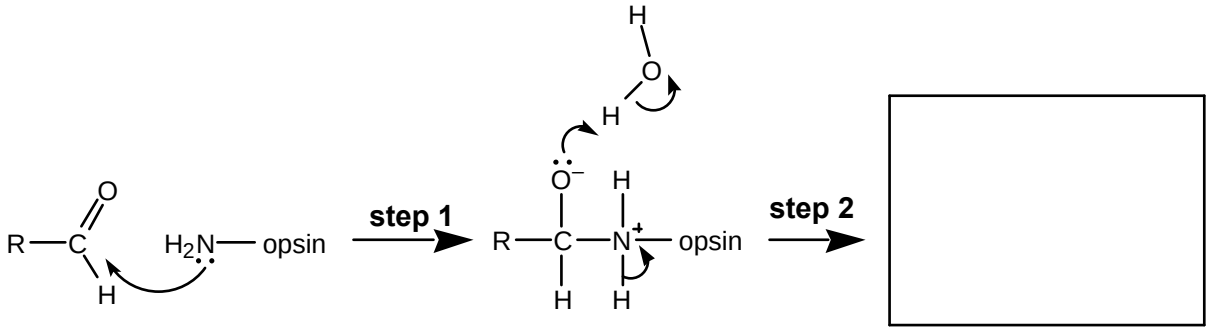
cis-retinal (incomplete)

Candidate style answer	*Examiner's commentary*
	The formula in part **(i)** is correct.

(ii) Why are the *cis* and *trans* isomers of a compound not identical? [1]

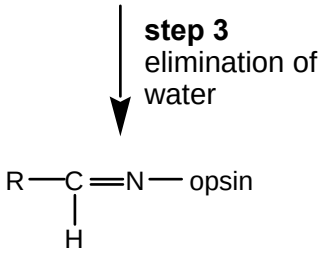
Candidate style answer	*Examiner's commentary*
because they are stereoisomers	Part **(ii)** is a correct statement but it does not answer the question – the answer should be in terms of lack of free rotation around the C=C double bond.

(d) The cis–retinal binds to the protein opsin to form rhodopsin. Part of the mechanism of this reaction is shown below.



***cis*–retinal**

compound X



rhodopsin

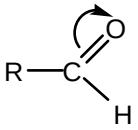
(i) Name the functional group on opsin which is reacting with the aldehyde group on cis retinal. [1]

Candidate style answer	*Examiner's commentary*
amine	

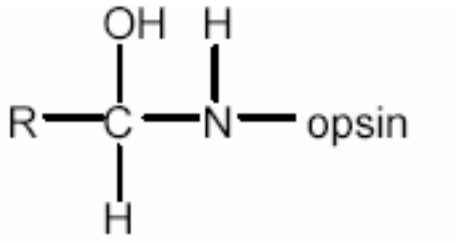
(ii) Name the type of reaction mechanism which starts in step 1 and is completed in step 2. [2]

Candidate style answer	*Examiner's commentary*
nucleophilic addition	

(iii) Draw a 'curly arrow' on the cis-retinal molecule to complete the electron movements that occur in step 1. [1]



Candidate style answer	*Examiner's commentary*

(iv) Deduce a structure for compound X and draw it in the box above. [1]	
Candidate style answer	*Examiner's commentary*
	The paper finishes in style with completely correct answers to some quite tricky questions.

Overall banding: High

This candidate is clearly a good chemist. All the calculations are correct and many of the difficult parts have been answered well. There is a lack of attention to detail in many places which has cost the candidate quite a few marks. One such example is the use of the word ‘it’ in the benzene structure question.