IB ALL HL EQ P3 Nature of Science and Option B questions

3 Papers Included: Specimen Paper, May 2016 (only 1 Time zone issued by the IBO per session), November 2016

IB HL Human Biochem Option Mapped to Biochemistry Option for 2016

IB Paper 3 HL Maped for Option B for 2016 Specimen, Summer and Winter
Key Points

Nature of Science is a massive proportion of the Paper 3 exam than both SL and HL, but exact same questions in both papers! Also, the exact same questions for SL topics are used in HL, they just also include about 30% of the paper on HL only topics. If you were pushed for time, and really bad at this topic, just learning SL material would be much easier, and you could still score maybe a low 6 with only SL for the HL exam, providing patterns from this one year are continued.

Some topics that were examined often for the previous Human Biochemistry Option might also appear in this new Biochemistry Option:

- B2 Proteins,
- B3 Lipids,
- B7 Proteins and Enzymes and
- B8 Nucleic Acids

Contents

IB ALL HL EQ P3 Nature of Science and Option B questions ................................................................. 1
Nature of Science ................................................................................................................................. 3
Topic 2 .................................................................................................................................................. 13
Topic 3 .................................................................................................................................................. 18
Topic 4 .................................................................................................................................................. 22
Topic 5 .................................................................................................................................................. 25
Topic 6 .................................................................................................................................................. 25
Topic 7 .................................................................................................................................................. 27
Topic 8 .................................................................................................................................................. 30
Topic 9 .................................................................................................................................................. 31
Mark Scheme......................................................................................................................................... 35
Nature of Science
Chem NoS 11 Q# 1/IB Chem/2016/w/TZ0/Paper 3/Higher Level/Q1

1. In order to provide safe drinking water, a water supply is often treated with disinfectants, which aim to inactivate disease-causing bacteria in the water.

To compare the effectiveness of different disinfectants, a CT value is used as a measure of the dosage of disinfectant needed to achieve a certain level of inactivation of specific bacteria.

CT value (mg min dm$^{-3}$) = $C$ (mg dm$^{-3}$) $\times$ $T$ (min)

centration of disinfectant contact time with water

(a) The table below compares the CT values of different disinfectants necessary to achieve 99% inactivation of two types of bacteria, listed as A and B.

<table>
<thead>
<tr>
<th>Disinfectant</th>
<th>CT value / mg min dm$^{-3}$ for 99% inactivation of bacteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hypochlorous acid, HOCl</td>
<td>4 x 10$^{-2}$ for Bacterium A, 8 x 10$^{-2}$ for Bacterium B</td>
</tr>
<tr>
<td>Hypochlorite ion, OCl$^{-}$</td>
<td>9.2 x 10$^{-1}$ for Bacterium A, 3.3 for Bacterium B</td>
</tr>
<tr>
<td>Chlorine dioxide, ClO$_2$</td>
<td>1.8 x 10$^{-1}$ for Bacterium A, 1.3 x 10$^{-1}$ for Bacterium B</td>
</tr>
<tr>
<td>Monochloramine, NH$_2$Cl</td>
<td>64 for Bacterium A, 94 for Bacterium B</td>
</tr>
</tbody>
</table>

(i) Deduce the oxidation state of chlorine in the following disinfectants. [1]

HOCl:

ClO$_2$:

(ii) From the data on CT values, justify the statement that bacterium B is generally more resistant to disinfection than bacterium A. [1]

(iii) CT values can be used to determine whether a particular treatment process is adequate. Calculate the CT value, in mg min dm$^{-3}$, when 1.50 x 10$^{-8}$ g dm$^{-3}$ of chlorine dioxide is added to a water supply with a contact time of 9.82 minutes. [1]
(iv) From your answer to (a) (iii) and the data in the table, comment on whether this
treatment will be sufficient to inactivate 99% of bacteria A.

(b) CT values are influenced by temperature and by pH. The table below shows the
CT values for chlorine needed to achieve 99% inactivation of a specific bacterium at
stated values of pH and temperature.

<table>
<thead>
<tr>
<th>pH</th>
<th>Temperature / °C</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.5</td>
</tr>
<tr>
<td>6.0</td>
<td>97</td>
</tr>
<tr>
<td>7.0</td>
<td>137</td>
</tr>
<tr>
<td>8.0</td>
<td>197</td>
</tr>
<tr>
<td>9.0</td>
<td>281</td>
</tr>
</tbody>
</table>

(i) With reference to the temperature data in the table, suggest why it may be more
difficult to treat water effectively with chlorine in cold climates.

(ii) Sketch a graph on the axes below to show how the CT value (at any
temperature) varies with pH.
(iii) Comment on the relative CT values at pH 6.0 and pH 9.0 at each temperature.

(iv) Chlorine reacts with water as follows:

\[
\text{Cl}_2(g) + \text{H}_2\text{O}(l) \rightleftharpoons \text{HOCl}(aq) + \text{HCl}(aq)
\]

\[
\text{HOCl}(aq) \rightleftharpoons \text{OCl}^{-}(aq) + \text{H}^+(aq)
\]

Predict how the concentrations of each of the species \(\text{HOCl}(aq)\) and \(\text{OCl}^{-}(aq)\) will change if the pH of the disinfected water increases.

HOCl(aq):

OCl\(^{-}\)(aq):

(c) Despite widespread improvements in the provision of safe drinking water, the sale of bottled water has increased dramatically in recent years. State one problem caused by this trend.

(c) List two assumptions made in this experiment.
2. Thomas wants to determine the empirical formula of red-brown copper oxide. The method he chooses is to convert a known amount of copper(II) sulfate into this oxide. The steps of his procedure are:

- Make 100 cm$^3$ of a 1 mol dm$^{-3}$ solution using hydrated copper(II) sulfate crystals.
- React a known volume of this solution with alkaline glucose in order to convert it to red-brown copper oxide.
- Separate the precipitated oxide and find its mass.

(a) Thomas calculates that he needs $0.1 \times [1 \times 63.55 + 1 \times 32.07 + 4 \times 16.00] = 15.962 \pm 0.001$ g of the copper(II) sulfate to make the solution. Outline the major error in his calculation. [1]

(b) He now adds 100 ± 1 cm$^3$ of water from a measuring/graduated cylinder and dissolves the copper(II) sulfate crystals. A friend tells him that for making standard solutions it is better to use a volumetric flask rather than adding water from a measuring cylinder. Suggest two reasons why a volumetric flask is better. [2]

(c) Thomas now heats 25 cm$^3$ of the solution with excess alkaline glucose to convert it to a suspension of red-brown copper oxide. Describe how he can obtain the pure, dry solid product. [2]
(d) Using the same chemical reactions, suggest how Thomas’ method to determine the mass of red-brown copper oxide that could be obtained from a known mass of copper(II) sulfate crystals might be simplified to produce more precise results. [1]

Chem NoS 9 Q# 3/ IB Chem/2016/s/TZoSP/Paper 3/Higher Level/Q1

1. Compounds used to generate cooling in refrigerators and air-conditioning systems are known as refrigerants. A refrigerant undergoes a reversible change of state involving vaporization and condensation. The search for suitable refrigerants has occupied chemists for approximately 200 years.

Previously, the most popular refrigerants were chlorofluorocarbons (CFCs), but these have been replaced first by hydrochlorofluorocarbons (HCFCs) and more recently by hydrofluorocarbons (HFCs).

Some data on examples of these three classes of refrigerants are shown below.

<table>
<thead>
<tr>
<th>Class</th>
<th>Compound</th>
<th>ODP(^1)</th>
<th>GWP(^2) over 100 years</th>
<th>(\Delta H_{\text{vap}}) (^3) / kJ mol(^{-1})</th>
<th>Atmospheric lifetime / years</th>
</tr>
</thead>
<tbody>
<tr>
<td>CFC</td>
<td>CCl(_3)F</td>
<td>1.0</td>
<td>4000</td>
<td>24.8</td>
<td>45</td>
</tr>
<tr>
<td>CFC</td>
<td>CCl(_2)F(_2)</td>
<td>1.0</td>
<td>8500</td>
<td>20.0</td>
<td>102</td>
</tr>
<tr>
<td>HCFC</td>
<td>CHCl(_2)CF(_3)</td>
<td>0.02</td>
<td>90</td>
<td>26.0</td>
<td>1</td>
</tr>
<tr>
<td>HCFC</td>
<td>CHClF(_2)</td>
<td>0.05</td>
<td>1810</td>
<td>20.2</td>
<td>12</td>
</tr>
<tr>
<td>HFC</td>
<td>CH(_2)FCF(_3)</td>
<td>0</td>
<td>1100</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>HFC</td>
<td>CHF(_2)CF(_3)</td>
<td>0</td>
<td>3500</td>
<td>30.0</td>
<td>32</td>
</tr>
</tbody>
</table>

\(^1\) ODP: The ozone depletion potential (ODP) is a relative measure of the amount of degradation to the ozone layer caused by the compound. It is compared with the same mass of CCl\(_3\)F, which has an ODP of 1.0.

\(^2\) GWP: The global warming potential (GWP) is a relative measure of the total contribution of the compound to global warming over the specified time period. It is compared with the same mass of CO\(_2\), which has a GWP of 1.0.

\(^3\) \(\Delta H_{\text{vap}}\): Defined as the energy required to change one mole of the compound from a liquid to a gas.
(a) (i) Explain why the values for ODP and GWP have no units. [1]

(ii) By making reference to the chemical formulas and ODP values of the compounds, comment on the hypothesis that chlorine is responsible for ozone depletion. [1]

(b) Use data from the table to interpret the relationship between the atmospheric lifetime of a gas and its GWP. [2]
(c) The graph shows the change in levels with time of equal masses of CO₂ and CH₂FCF₃ introduced into the atmosphere.

![Graph showing the percentage of CO₂ and CH₂FCF₃ remaining in the atmosphere over time.]

(i) Apply IUPAC rules to state the name of CH₂FCF₃. [1]

........................................................................................................

(ii) The ΔH_vaporization for CH₂FCF₃ is 217 kJ/kg⁻¹. Calculate the value of the enthalpy change for the condensation of one mole of CH₂FCF₃. [2]

........................................................................................................

........................................................................................................

........................................................................................................

........................................................................................................

........................................................................................................

........................................................................................................
(iii) With reference to the graph on page 4, comment on the atmospheric lifetime of CO₂ relative to CH₂FCF₃, and on the likely influence of this on climate change. [2]

2. A student wished to determine the concentration of a solution of sodium hydroxide by titrating it against a 0.100 mol dm⁻³ aqueous solution of hydrochloric acid.

4.00 g of sodium hydroxide pellets were used to make 1.00 dm³ aqueous solution.

20.0 cm³ samples of the sodium hydroxide solution were titrated using bromothymol blue as the indicator.

(a) Outline, giving your reasons, how you would carefully prepare the 1.00 dm³ aqueous solution from the 4.00 g sodium hydroxide pellets. [2]

(b) (i) State the colour change of the indicator that the student would see during his titration using section 22 of the data booklet. [1]
(ii) The student added the acid too quickly. Outline, giving your reason, how this could have affected the calculated concentration.

(c) Suggest why, despite preparing the solution and performing the titrations very carefully, widely different results were obtained.

Chem NoS 9 Q# 5/ IB Chem/2016/s/TZ0/Paper 3/Higher Level/Q1

1. The absorption of infrared (IR) radiation by molecules in the atmosphere affects global temperatures.

Graph of IR absorbances for oxygen and ozone molecules

![Graph of IR absorbances for oxygen and ozone molecules](image)


(a) Using the graph, state, giving your reasons, whether or not oxygen and ozone are greenhouse gases.
(b) The following data has been compiled for a range of molecules that may be found in the atmosphere.

<table>
<thead>
<tr>
<th>Molecule</th>
<th>Integrated IR intensity* / km mol⁻¹</th>
<th>Molecular dipole moment / Debyes</th>
<th>GWP** over 100 years</th>
</tr>
</thead>
<tbody>
<tr>
<td>CO₂</td>
<td>25.7</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>CCl₄</td>
<td>443.7</td>
<td>0</td>
<td>1400</td>
</tr>
<tr>
<td>CCl₃F</td>
<td>705.2</td>
<td>0.45</td>
<td>4750</td>
</tr>
<tr>
<td>CCl₂F₂</td>
<td>970.1</td>
<td>0.51</td>
<td>10,900</td>
</tr>
<tr>
<td>CCIF₃</td>
<td>1199</td>
<td>0.50</td>
<td>14,400</td>
</tr>
<tr>
<td>CF₄</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>


*Integrated IR intensity is a measure of the extent to which the molecule absorbs infrared radiation passing through the atmosphere.

**GWP: The global warming potential (GWP) is a relative measure of the total contribution of the compound to global warming over the specified time period. It is compared to the same mass of CO₂, which has a GWP of 1.

(i) Use the integrated IR intensity data in the table to estimate the value for CF₄.

(ii) Explain the increase in molecular dipole moment as one chlorine atom in CCl₄ is replaced with fluorine to produce CCl₃F.
(iii) Outline the relationship between GWP over 100 years and integrated IR intensity for CCl₄, CCl₃F, CCl₂F₂ and CClF₃.

(iv) Examine whether there is a general relationship between integrated IR intensity and molecular dipole moment.

(v) CCl₂F₂ and CClF₃ were developed for use as refrigerants but are now being replaced by other chemicals. Comment on their use with reference to values in the table and other environmental concerns.

---

**Topic 2**


13. Amino acids are usually identified by their common names. Use section 33 of the data booklet.

(b) A mixture of amino acids is separated by gel electrophoresis at pH 6.0. The amino acids are then stained with ninhydrin.

(i) On the diagram below draw the relative positions of the following amino acids at the end of the process: Val, Asp, Lys and Thr.
(b) A mixture of amino acids is separated by gel electrophoresis at pH 6.0. The amino acids are then stained with ninhydrin.

(i) On the diagram below draw the relative positions of the following amino acids at the end of the process: Val, Asp, Lys and Thr. [2]

(ii) Suggest why glycine and isoleucine separate slightly at pH 6.5. [1]

(d) The castor seed contains ricin, a toxic protein which is fatal in small doses. During the oil extraction process, the toxin is inactivated by heating.

(i) Outline why ricin loses its toxic effects on being heated. [1]

(ii) Examine why many countries no longer harvest the castor plant but rely instead on imports of castor oil from other countries. [2]
(c) The reaction in part (b) is catalysed by the enzyme maltase. Experiments were carried out to investigate the rate of breakdown of maltose in the presence of maltase over a range of pH values from 4 to 11. The results are shown below.

Describe how the activity of the enzyme changes with pH, including in your answer specific reference to how the pH is affecting the enzyme at X, Y and Z. [3]
(b) The pigments from spinach were separated using chromatography. Identify Z by calculating its \( R_f \) value and using the data table.

<table>
<thead>
<tr>
<th>Pigment</th>
<th>( R_f ) value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Xanthophyll</td>
<td>0.35</td>
</tr>
<tr>
<td>Chlorophyll a</td>
<td>0.60</td>
</tr>
<tr>
<td>Chlorophyll b</td>
<td>0.50</td>
</tr>
<tr>
<td>Carotene</td>
<td>0.95</td>
</tr>
</tbody>
</table>


(d) Bioplastics are broken down by enzyme catalysed reactions. Sketch a graph illustrating how the rate of this reaction varies with pH.

10. Amino acids, shown in section 33 of the data booklet, can be combined to form polypeptides and proteins.

(a) Deduce the structures of the most abundant form of glycine in three buffer solutions at pH 1.0, 6.0 and 11.0. Glycine \( pK_{a1} = 2.4 \); \( pK_{a2} = 9.8 \).  

<table>
<thead>
<tr>
<th>pH 1.0</th>
<th>pH 6.0</th>
<th>pH 11.0</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

(b) A tripeptide, \( X \), containing leucine (Leu), lysine (Lys) and glutamic acid (Glu) is hydrolysed and separated by gel electrophoresis in a buffer solution with a pH of 6.0.

(i) Predict the result of the electrophoresis by labeling the three spots below with the names of the amino acids.

(ii) Deduce the number of tripeptides that could be formed by using the three amino acids of tripeptide \( X \).
11. Lipids are an important part of the human diet.

(a) Fatty acids react with glycerol to form fats and oils. State the name of the chemical link formed in this reaction and the name of the other product. [1]

Name of the chemical link: .................................................................

Name of the other product: .................................................................

(b) The table below shows average figures for the percentage fatty acid composition of some common fats and oils.

<table>
<thead>
<tr>
<th>Source of fat or oil</th>
<th>% saturated fatty acids (total)</th>
<th>% monounsaturated fatty acid oleic</th>
<th>% polyunsaturated fatty acids linoleic</th>
<th>% polyunsaturated fatty acids linolenic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beef fat</td>
<td>59</td>
<td>38</td>
<td>3</td>
<td>-</td>
</tr>
<tr>
<td>Coconut oil</td>
<td>90</td>
<td>8</td>
<td>2</td>
<td>-</td>
</tr>
<tr>
<td>Corn oil</td>
<td>25</td>
<td>26</td>
<td>47</td>
<td>2</td>
</tr>
<tr>
<td>Cotton seed oil</td>
<td>22</td>
<td>35</td>
<td>43</td>
<td>-</td>
</tr>
<tr>
<td>Olive oil</td>
<td>15</td>
<td>78</td>
<td>7</td>
<td>-</td>
</tr>
<tr>
<td>Soybean oil</td>
<td>14</td>
<td>28</td>
<td>50</td>
<td>8</td>
</tr>
</tbody>
</table>

(i) Deduce, with a reason, which fat or oil from the table above has the lowest iodine number. [1]

(ii) Deduce, with a reason, which fat or oil from the table above is most likely to become rancid when exposed to the air. [1]
(iii) The P/S Index of a fat or oil is the ratio of polyunsaturated fat to saturated fat present. It is sometimes used to compare the relative health benefits of different lipids in the diet. Calculate the P/S index of beef fat and soybean oil.

Beef fat:

Soybean oil:

(iv) Suggest why a P/S index of greater than 1 is considered beneficial to health.

(v) Cotton seed oil and corn oil have similar iodine numbers but the melting point of cotton seed oil is higher than that of corn oil. Suggest an explanation in terms of the structure and bonding in these two oils.
9. The castor plant is grown as a crop for its oil. Castor oil is mostly a triglyceride of the relatively rare fatty acid ricinoleic acid, whose structure is given below.

\[ \text{\includegraphics[width=0.8\textwidth]{ricinoleic_acid.png}} \]

(a) State the molecular formula of ricinoleic acid. \[1]\]

\[
\text{[Molecular formula of ricinoleic acid]} \]

(b) (i) Compare and contrast the structure of ricinoleic acid with stearic acid, whose structure is given in section 34 of the data booklet. \[3]\]

\[
\text{[Comparison and contrast between ricinoleic and stearic acids]} \]
(ii) State and explain how you would expect ricinoleic acid triglyceride to differ from stearic acid triglyceride in its tendency to undergo oxidative rancidity.

(a) (i) State the name of the functional group circled in the DHEA molecule shown below.

(ii) Identify the characteristic of this structure that classifies it as a steroid.

(b) The production of banned steroids has ethical implications. Suggest a reason why steroid research might be supported.
12. Carbohydrates are energy-rich molecules which can be synthesized in some plant cells from inorganic compounds.

(a) State the raw materials and source of energy used in the process described above. [1]

........................................................................................................................................
........................................................................................................................................

(b) The structures of two molecules, X and Y, are shown below.

\(X: \quad \text{H} \quad \text{C} \quad \text{C} \quad \begin{array}{c} \text{O} \\ \text{C} \quad \text{H} \quad \text{OH} \\ \text{H} \quad \text{C} \quad \text{OH} \\ \text{H} \end{array} \quad \text{Y:} \quad \text{H} \quad \text{C} \quad \text{C} \quad \begin{array}{c} \text{O} \\ \text{C} \quad \text{H} \quad \text{OH} \\ \text{H} \end{array} \)

(i) Justify why both these molecules are carbohydrates. [1]

........................................................................................................................................
........................................................................................................................................

(ii) Distinguish between these molecules in terms of their functional groups. [1]

........................................................................................................................................
........................................................................................................................................
(c) Amylose is an unbranched polysaccharide composed of repeating units of glucose.

(i) Draw the structure of the repeating unit of amylose. Use section 34 of the data booklet.

(ii) Amylose is a major component of starch. Corn starch can be used to make replacements for plastics derived from oil, especially for packaging. Discuss one potential advantage and one disadvantage of this use of starch.

Advantage:

Disadvantage:

8. The diagram below shows the structure of a disaccharide called maltose.
11. Glucose, C₆H₁₂O₆, is a monosaccharide that our body can use as a source of energy.

(a) Deduce the equation for the cellular respiration of glucose. [1]

(b) Calculate the energy, in kJ, produced from 15.0 g of glucose if its enthalpy of combustion is –2803 kJ mol⁻¹. [2]
**Topic 5**

Chem OpB 5 2 Q# 19/ IB Chem/2016/s/TZ0/Paper 3/Higher Level/

13. Spinach is an excellent source of vitamins A and C.

(a) Identify one structural characteristic in vitamins A and D which makes them more similar to each other than they are to vitamin C using section 35 of the data booklet. [1]

........................................................................................................................................

........................................................................................................................................

**Topic 6**

Chem OpB 6 3 Q# 20/ IB Chem/2016/s/TZ0SP/Paper 3/Higher Level/

10. The figure below shows two examples of molecules known as xenoestrogens, a type of xenobiotic. They have effects on living organisms similar to those of the female hormone estrogen. These compounds are found in the environment and can be taken up by living organisms, where they may be stored in certain tissues.

![Chemical Structures](image)

(a) State what is meant by the term xenobiotic. [1]
(b) With reference to their structures, outline why these xenobiotics are stored easily in animal fat. [1]

(c) One way to decrease the concentration of a xenobiotic in the environment is to develop a specific molecule, a “host”, that can bind to it. The binding between the host and the xenobiotic forms a supramolecule.

State three types of association that may occur within the supramolecule between the host and the xenobiotic. [1]

Two advantages:

Two disadvantages:
14. Glucokinase and hexokinase are both enzymes that catalyse the conversion of glucose to glucose-6-phosphate. The enzymes differ, however, in their affinity for the substrate, as shown in the graph below.

![Graph showing relative velocity vs. glucose concentration for hexokinase and glucokinase.]

[Source: http://themedicalbiochemistrypage.org/glycolysis.php]

(a) (i) Estimate the $K_m$ values of the two enzymes. [1]

$K_m$ hexokinase:

$K_m$ glucokinase:

(ii) Suggest, with a reason, which enzyme will be more responsive to changes in the concentration of glucose in the blood. [1]
(b)  (i) Outline what is meant by product inhibition as it applies to hexokinase.  

(ii) Product inhibition of hexokinase does not affect its $K_m$ value. Using this information, deduce the type of binding site that the inhibitor attaches to.

13. Amino acids are usually identified by their common names. Use section 33 of the data booklet.

(a) State the IUPAC name for leucine.

(c) Amino acids act as buffers in solution. In aspartic acid, the side chain (R group) carboxyl has $pK_a = 4.0$. Determine the percentage of the side chain carboxyl that will be ionized ($-\text{COO}^-$) in a solution of aspartic acid with $pH = 3.0$. Use section 1 of the data booklet.
Chem OpB 7 3 Q# 24/ IB Chem/2016/s/TZoSP/Paper 3/Higher Level/Q8

(d) The experiments described in part (c) use a range of buffer solutions. A student needed to make 1.00 dm$^3$ of pH 5.00 buffer solution starting with 0.10 mol dm$^{-3}$ butanoic acid solution and solid sodium butanoate. The molar mass of sodium butanoate is 110.01 gmol$^{-1}$.

Use information from sections 1 and 21 of the data booklet to determine how much of each component the student should mix together. Assume no volume change occurs on mixing. Show all your working.


12. Enzymes play an important role in the functioning of our bodies.

(a) The graph below shows a Michaelis–Menten plot for an enzyme. Sketch and label two curves on the graph below to show the effect of adding a competitive and non-competitive inhibitor.
(b) Enzyme solutions are prepared in buffers. Determine the pH of a buffer solution containing $2.60 \times 10^{-3}\text{mol dm}^{-3}$ ethanoic acid and $3.70 \times 10^{-3}\text{mol dm}^{-3}$ sodium ethanoate. Refer to sections 1 and 21 of the data booklet. [2]

---

**Topic 8**

Chem OpB 8 2 Q# 26/ IB Chem/2016/w/TZ0/Paper 3/Higher Level/Q15

15. The structure of DNA (deoxyribonucleic acid) has been studied in many different ways.

(a) State the name of the component of DNA responsible for the migration of its fragments to the positive electrode in gel electrophoresis. [1]

---

(b) In 2010, scientists claimed that they had discovered a species of bacteria capable of incorporating arsenic in place of phosphorus into the bacterial DNA. This claim has since proved controversial. Suggest one technique or evidence that might help support the claim. [1]

---
11. DNA is the molecule that carries genetic information in nearly all cells. Two months before Watson and Crick published their paper describing the double helical nature of DNA in 1953, Linus Pauling published a suggested structure for DNA based on a triple helix. Pauling’s model, which was soon proved to be incorrect, had the phosphate groups facing into the core of the helix and the nitrogenous bases facing out.

(a) Suggest why Pauling’s model would not have been a stable structure for DNA.  

(b) DNA has the unusual property of being able to replicate. State the type and position of the bonds that break at the start of the replication process.  

---

**Topic 9**

16. Anthocyanins are pigments that give colour to many flowers and fruits. The red colour of ripe strawberries is mainly due to the anthocyanin pigment whose structure is shown below.
(a) Outline why this molecule absorbs visible light.

(b) With reference to its chemical structure, outline whether this pigment is found in aqueous solution in the cells or in the lipid-based membranes.

(c) A student investigated the ability of anthocyanins to act as pH indicators. He extracted juice from blackberries and used a UV-vis spectrophotometer to produce absorption spectra at different pH values. His results are shown below.

![Absorption spectra graph]

Deduce the colour of the juice at each pH, giving your reasoning. Use section 17 of the data booklet.
12. Hemoglobin is a protein with a quaternary structure. The graph below shows the relationship between the percentage saturation of hemoglobin with oxygen and the oxygen partial pressure, which is a measure of its concentration.

\[ \text{Oxygen partial pressure / kPa} \]
\[ \text{% saturation of hemoglobin} \]

(a) Describe why the curve rises steeply in the range of approximately 2 – 6 kPa

(b) (i) Annotate the graph above to show how the oxygen binding curve for hemoglobin changes in the presence of an increased concentration of carbon dioxide.

(ii) Explain how the change you have drawn in part (b)(i) affects the oxygen saturation of the blood when it is close to cells that are actively respiring.
14. Hemoglobin contains a heme group with an iron(II) ion.

(a) Outline how the oxygen saturation of hemoglobin is affected by changes in the blood plasma. [3]

(b) Explain why foetal hemoglobin has a greater affinity for oxygen. [2]

10. Amino acids, shown in section 33 of the data booklet, can be combined to form polypeptides and proteins.

(c) (i) Serine is a chiral amino acid. Draw both enantiomers of serine. [1]

(ii) State the enantiomeric form of serine found in proteins. [1]
Mark Scheme

Q# 1/ IB Chem/2016/w/TZ0/Paper 3/Higher Level/Q1

<table>
<thead>
<tr>
<th>Question</th>
<th>Answers</th>
<th>Notes</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. a i</td>
<td>HOCl = 1 AND ClO_2^- 4 ✓</td>
<td>Accept &quot;I&quot; and &quot;IV&quot; but not &quot;I+I&quot; and &quot;4+4&quot; notations.</td>
<td>1</td>
</tr>
<tr>
<td>1. a ii</td>
<td>&quot;most&quot; CT values are higher for &quot;bacterium&quot; B OR generally higher dosage needed for &quot;bacterium&quot; B ✓</td>
<td>Accept converse arguments. Accept &quot;concentration&quot; for &quot;dosage&quot;.</td>
<td>1</td>
</tr>
<tr>
<td>1. a iii</td>
<td>CT = 1.50 × 10^-6 mg dm^-3 × 9.62 min = 1.47 × 10^-7 mg min^-3 ✓</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>1. a iv</td>
<td>lower than CT value/minimum dosage/1.8 × 10^-7 mg min^-3 AND insufficient treatment ✓</td>
<td>Accept &quot;concentration&quot; for &quot;dosage&quot;.</td>
<td>1</td>
</tr>
<tr>
<td>1. b i</td>
<td>higher CT value at lower temperature OR higher dosage &quot;of chlorine&quot; needed at low temperature ✓</td>
<td>Accept effectiveness decreases at lower temperature. Accept &quot;concentration&quot; for &quot;dosage&quot;. Accept converse arguments.</td>
<td>1</td>
</tr>
<tr>
<td>1. b ii</td>
<td>labeled axes (y: CT and x: pH) AND curve with increasing gradient ✓</td>
<td>Do not accept axes the wrong way round. Accept a linear graph.</td>
<td>1</td>
</tr>
<tr>
<td>1. b iii</td>
<td>values at pH 9.0 approximately 3 times values at pH 6.0 OR increase in CT values in same ratio ✓</td>
<td>The exact ratio is 2.9 times. Do not accept just &quot;increase in value&quot;.</td>
<td>1</td>
</tr>
<tr>
<td>1. b iv</td>
<td>[HOCl] decreases AND [ClO] increases ✓</td>
<td></td>
<td>1</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Question</th>
<th>Answers</th>
<th>Notes</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. c</td>
<td>plastic disposal/pollution OR plastic bottles use up petroleum/non-renewable raw material OR chemicals in plastic bottles can contaminate water OR prolonged storage in plastic bottles can cause contamination of water OR plastic water bottles sometimes reused without proper hygiene considerations ✓</td>
<td>Accept other valid answers. Accept economic considerations such as &quot;greater production costs&quot;, &quot;greater transport costs&quot; or &quot;bottled water more expensive than tap water&quot;.</td>
<td>1</td>
</tr>
</tbody>
</table>

Q# 2/ IB Chem/2016/s/TZoSP/Paper 3/Higher Level/

<table>
<thead>
<tr>
<th>Question</th>
<th>Answers</th>
<th>Notes</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>2. a</td>
<td>forget to take account of water of crystallisation OR should have used 24,972 g ✓</td>
<td>GTINTE</td>
<td>1</td>
</tr>
<tr>
<td>2. b</td>
<td>less uncertainty in the volume OR more precise ✓ takes into account volume change on dissolving OR concentration is for a given volume of solution not volume of solvent ✓</td>
<td></td>
<td>2</td>
</tr>
<tr>
<td>2. c</td>
<td>filter OR centrifuge ✓ rinse (the solid) with water ✓ heat in an oven OR rinse with propylene/ethanol/volatile organic solvent and leave to evaporate ✓</td>
<td>Award [1] for all 3, [1] for any 2.</td>
<td>2</td>
</tr>
<tr>
<td>2. d</td>
<td>taking a known mass of the solid to react directly with glucose OR not making the standard solution ✓</td>
<td>GTINTE Accept any other valid answer based on sound scientific reasoning</td>
<td>1</td>
</tr>
</tbody>
</table>
Q# 3/ IB Chem/2016/s/TZ0/Paper 3/Higher Level/

<table>
<thead>
<tr>
<th>Question</th>
<th>Answers</th>
<th>Notes</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. a i</td>
<td>relative values OR compared with a standard OR not absolute measure ✓</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>a ii</td>
<td>high ODP for compounds with high Cl OR low ODP for compounds with less Cl OR zero ODP for compounds with no Cl ✓</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>b</td>
<td>increasing atmospheric lifetime correlates with increasing GWP ✓ total contribution to global warming depends on length of time in atmosphere OR GWP depends on efficiency of greenhouse gas and atmospheric lifetime ✓</td>
<td></td>
<td>2</td>
</tr>
<tr>
<td>c i</td>
<td>1,1,1,2-tetrafluoroethane ✓</td>
<td>Allow without commas or dashes.</td>
<td>1</td>
</tr>
<tr>
<td>c ii</td>
<td>( \text{M(CF}_3\text{CHF}_2) = (12.01 \times 2) + (0.01 \times 2) + (19.00 \times 4) = 102.04 \text{ (g/mol)}^2 ) ✓ ( \Delta H \text{ (condensation CF}_3\text{CHF}_2) = -[0.217 \text{ kJ g}^{-1}] \times 102.04 \text{ (g mol}^{-1}) = -22.1 \text{kJ mol}^{-1} ) ✓</td>
<td>Award [1 mark] for ( \Delta H = -22.1 \text{kJ} )</td>
<td>2</td>
</tr>
<tr>
<td>c iii</td>
<td>atmospheric lifetime CO(_2) much longer than CH(_3)CF(_2) OR after 100 years approx 30% CO(_2) still present whereas CH(_3)CF(_2) removed ✓ CO(_2) from current emissions will continue to effect climate change/global warming for into the future ✓</td>
<td>OMITTE</td>
<td>2</td>
</tr>
</tbody>
</table>

Q# 4/ IB Chem/2016/s/TZ0/Paper 3/Higher Level/

<table>
<thead>
<tr>
<th>Question</th>
<th>Answers</th>
<th>Notes</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>2. a</td>
<td>Key Procedural Steps: use volumetric flask ✓ mix the solution ✓ fill up to line/marker/level of 1 dm(^3) with deionized/distilled water ✓ Key Technique Aspects: use balance that reads to two decimal places/use analytical balance/use balance of high precision ✓ mix pellets in beaker with deionized/distilled water and stir with glass rod to dissolve ✓ use a funnel and glass rod to avoid loss of solution ✓ need to rinse the beaker, funnel and glass rods and transfer washings to the volumetric flask ✓ Safety Precautions: NaOH corrosive reacts with water exothermically ✓ keep NaOH in desiccator ✓ let the solution cool ✓</td>
<td>Two marks may be awarded from two different categories or from within one category. Do not accept “use of a funnel to transfer the solid” Do not accept “keep volumetric flask in cold waterbath”</td>
<td>2 max</td>
</tr>
<tr>
<td>2. b i</td>
<td>true to green/yellow ✓</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>2. b ii</td>
<td>equivalence point has been exceeded OR greater volume of too much acid has been added ✓ calculated concentration increased ✓</td>
<td>Accept “end point” for “equivalence point”</td>
<td>2</td>
</tr>
<tr>
<td>2. c</td>
<td>colour difficult to detect OR used different HCl standards OR no significant figures used in subsequent calculation OR incorrect method of calculation ✓</td>
<td>Accept any valid hypothesis. Do not accept any mistakes associated with technique (based on term of question) eg. parallax error, not rinsing glassware, etc. Do not accept “HCl was not standardized”. Accept “reaction of NaOH with CO(_2) from air”. Accept “NaOH hygroscopic/alumina, moisture, ( \text{CO}_2 ) from the atmosphere”. Accept “impurities in NaOH”. Accept “temperature changes during experiment”. Ignore a general reference to random errors.</td>
<td>1</td>
</tr>
</tbody>
</table>
Q# 5 / IB Chem/2016/s/TZ0/Paper 3/Higher Level/

<table>
<thead>
<tr>
<th>Question</th>
<th>Answers</th>
<th>Notes</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. a</td>
<td>Ozone: yes because it absorbs IRs. IR active ✓</td>
<td>Award [1 max] for stating “ozone/O&lt;sub&gt;3&lt;/sub&gt; is a greenhouse gas but oxygen/O&lt;sub&gt;2&lt;/sub&gt; is not.” Award [1 max] for stating “ozone/O&lt;sub&gt;3&lt;/sub&gt; absorbs IRs, IR active but oxygen/O&lt;sub&gt;2&lt;/sub&gt; does not absorb IRs, IR inactive”. Accept “oxygen/O&lt;sub&gt;2&lt;/sub&gt; is not a greenhouse gas because it absorbs UV”.</td>
<td>2</td>
</tr>
<tr>
<td>1. b i</td>
<td>Any value or range within the range: 1000-1500 kJ mol&lt;sup&gt;-1&lt;/sup&gt; ✓</td>
<td>(It is in fact 1403 kJ mol&lt;sup&gt;-1&lt;/sup&gt; using the same measurement technique as that used to get the data in the table).</td>
<td>1</td>
</tr>
<tr>
<td>1. b ii</td>
<td>CCl&lt;sub&gt;4&lt;/sub&gt; is symmetrical; dipoles of C-Cl bonds cancel out. OR C-F bond more polar than C-Cl bond ✓</td>
<td>Accept suitable diagrams with dipoles represented as vectors illustrating M1 and/or M2. Accept “fluorine/F is more electronegative than chlorine/Cl” for M1. Accept converse statements throughout. Accept “dipoles will not cancel out in CCl&lt;sub&gt;4&lt;/sub&gt;” for M2.</td>
<td>2</td>
</tr>
<tr>
<td>1. b iii</td>
<td>GWP increases as IR intensity increases ✓</td>
<td>Accept “GWP proportional to IR intensity”. Accept “there is a positive correlation relationship”. Accept converse statements.</td>
<td>1</td>
</tr>
<tr>
<td>1. b iv</td>
<td>No relationship AND CO&lt;sub&gt;2&lt;/sub&gt; and CCl&lt;sub&gt;4&lt;/sub&gt; are non-polar: have zero dipole moment. Both have very different integrated IR intensities OR no relationship AND COCl&lt;sub&gt;2&lt;/sub&gt; and COClF&lt;sub&gt;2&lt;/sub&gt; have almost the same dipole moment but have very different integrated IR intensities OR no relationship AND sometimes there is a positive relationship between the two variables and sometimes there is a negative/no relationship between them OR no relationship AND as F atoms are gradually added to CO&lt;sub&gt;2&lt;/sub&gt;, integrated IR intensity always increases while dipole moment decreases ✓</td>
<td>Accept a plot or sketch with a comment that “changes along y-axis produce random changes along x-axis”. Accept “yes there is a relationship, as there is still a weak overall statistical positive correlation”. Accept “dipole” for “dipole moment”.</td>
<td>1</td>
</tr>
<tr>
<td>1. b v</td>
<td>Data from table such as integrated IR and GWP indicate that they contribute significantly to global warming/enhanced greenhouse effect ✓</td>
<td>Do not just accept “contributes to global warming” without an indication that the effect is large. Do not accept just “contributes significantly to climate change”. Award [1 max] for “persistent in atmosphere”. Accept a consequence of global warming for M2.</td>
<td>2</td>
</tr>
</tbody>
</table>

Q# 6 / IB Chem/2016/w/TZ0/Paper 3/Higher Level/Q13

13. b i   | ![Diagram](image) | Val and Thr need not overlap. Accept any (reasonable) size and demarcation of position so long as position relative to origin is correct. Accept crosses for spots. Award [1 max] for any two correct. Award [1 max] if net direction of spots is reversed. Award [1 max] if the four points are in the correct order but not in a straight line. | 2 |
Q# 7/ IB Chem/2016/s/TZ0/Paper 3/Higher Level/Q9

<table>
<thead>
<tr>
<th>Q# 7/ IB Chem/2016/s/TZ0/Paper 3/Higher Level/Q9</th>
</tr>
</thead>
</table>
| d i  | (heating causes) denaturation  
OR  
(heating causes) loss of conformation  
OR  
(heating causes) change of shape  
OR  
(heating causes) inability to bind substrates ✓  | Do not accept inactivated.  |
| d ii | easier seeds contain toxins / venom  
OR  
ingesting raw seeds can be fatal ✓  
OR  
different health / safety standards in different countries  
OR  
richer countries exploit workers in less developed / poorer countries ✓  | Accept alternate valid answers, such as economic considerations.  |

Q# 8/ IB Chem/2016/s/TZ0/Paper 3/Higher Level/Q

<table>
<thead>
<tr>
<th>Q# 8/ IB Chem/2016/s/TZ0/Paper 3/Higher Level/Q</th>
</tr>
</thead>
</table>
| c | at X (low pH) enzyme protein protonated / positively charged / cationic (so unable to bind effectively) ✓  
at Y (optimum pH) enzyme maximally able to bind to substrate / anion  
at Z (high pH) enzyme protein deprotonated / negatively charged / anionic (so unable to bind effectively) ✓  | Award [1 mark] for reference to denaturation / change in shape of active site without explanation in terms of changes in ionization.  |

Q# 9/ IB Chem/2016/s/TZ0/Paper 3/Higher Level/

<table>
<thead>
<tr>
<th>Q# 9/ IB Chem/2016/s/TZ0/Paper 3/Higher Level/</th>
</tr>
</thead>
<tbody>
<tr>
<td>13. b</td>
</tr>
</tbody>
</table>

Q# 10/ IB Chem/2016/s/TZ0/Paper 3/Higher Level/

<table>
<thead>
<tr>
<th>Q# 10/ IB Chem/2016/s/TZ0/Paper 3/Higher Level/</th>
</tr>
</thead>
<tbody>
<tr>
<td>![Graph Image]</td>
</tr>
<tr>
<td>--------------------------------------------------</td>
</tr>
</tbody>
</table>
| 11. d | Reaction rate  
[pH] | typical curve as shown in example above ✓  | Accept any curve with a single maximum (not just bell-shaped).  
Ignore features such as pH values on a pH scale or a pH value at maximum (if given).  
Do not penalize if curve does not touch the x-axis.  | 1 |

Q# 11/ IB Chem/2016/s/TZ0/Paper 3/Higher Level/

<table>
<thead>
<tr>
<th>Q# 11/ IB Chem/2016/s/TZ0/Paper 3/Higher Level/</th>
</tr>
</thead>
</table>
| ![Chemical Structures] | pH 1.0  
H | pH 6.0  
H | pH 11.0  
H |  | Charges must be shown on the correct atoms in each structure for mark. Penalize repeated mistakes once.  
Although question asks specifically for structures, accept condensed structural formulas, but charges must be given.  | 3 |

Q# 12/ IB Chem/2016/s/TZ0/Paper 3/Higher Level/

<table>
<thead>
<tr>
<th>Q# 12/ IB Chem/2016/s/TZ0/Paper 3/Higher Level/</th>
</tr>
</thead>
<tbody>
<tr>
<td>![Amino Acid Images]</td>
</tr>
<tr>
<td>--------------------------------------------------</td>
</tr>
</tbody>
</table>
| 10. b i |  | Gla  
Leu  
Lys ✓  | Award [2] for correct order.  
Award (1 mark) for Leu in centre if order is incorrect.  | 2 |
| 10. b ii |  | ✓  | Accept 27.  | 1 |
Q# 13/ IB Chem/2016/w/TZ0/Paper 3/Higher Level/Q11

<table>
<thead>
<tr>
<th>Question</th>
<th>Answers</th>
<th>Notes</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>11. a</td>
<td>Name of the chemical link: ester AND Name of the other product: water</td>
<td>Do not accept formulas. Do not accept “esterification”.</td>
<td>1</td>
</tr>
<tr>
<td>11. b i</td>
<td>coconut oil AND lowest percentage of unsaturated fatty acids OR coconut oil AND smallest number of C=C bonds OR coconut oil AND highest percentage of saturated fatty acids</td>
<td>Accept “fats” for “fatty acids”.</td>
<td>1</td>
</tr>
<tr>
<td>11. b ii</td>
<td>soybean oil AND highest percentage of polyunsaturated fatty acids OR soybean oil AND greatest number of C=C bonds OR soybean oil AND lowest percentage of saturated fatty acids</td>
<td>Accept “fats” for “fatty acids”.</td>
<td>1</td>
</tr>
<tr>
<td>11. b iii</td>
<td>Beef fat: [ \frac{1}{\text{P/S}} = \frac{3}{50} \rightarrow 0.06 ] AND Soybean oil: [ \frac{1}{\text{P/S}} = \frac{50 - 8}{14} \rightarrow 4.1 ]</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>11. b iv</td>
<td>Higher proportion of polyunsaturated fatty acids decrease risk of atherosclerosis/heart disease/cardiovascular disease/CVD OR Higher proportion of polyunsaturated fatty acids which are less likely to be deposited on the walls of arteries (than saturated fatty acids)</td>
<td>Accept converse arguments. Accept correct arguments in terms of HDL and LDL but not in terms of “good” and “bad” cholesterol. Accept “fats” for “fatty acids”.</td>
<td>1</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Question</th>
<th>Answers</th>
<th>Notes</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>11. b v</td>
<td>Any two of: cotton seed oil has a higher proportion of longer chain/greater molar mass fatty acids OR molecules of cotton seed oil have greater surface area/higher electron density OR stronger London dispersion/ instantaneous induced dipole-induced dipole forces “between chains” in cotton seed oil</td>
<td>Accept converse arguments. Accept “molecules of cotton seed oil are packed more closely/have more regular structure” for M2.</td>
<td>2 max</td>
</tr>
</tbody>
</table>

Q# 14/ IB Chem/2016/s/TZ0SP/Paper 3/Higher Level/

<table>
<thead>
<tr>
<th>Question</th>
<th>Answers</th>
<th>Notes</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>9. a</td>
<td>( \text{C}<em>6\text{H}</em>{12}\text{O}_6 )</td>
<td>✔️</td>
<td>1</td>
</tr>
<tr>
<td>9. b i</td>
<td>both have 18 carbon atoms ✔️</td>
<td></td>
<td>3 max</td>
</tr>
<tr>
<td></td>
<td>both have COOH carboxylic acid group OR both are fatty acids ✔️</td>
<td></td>
<td>3 max</td>
</tr>
<tr>
<td></td>
<td>ricinoleic acid has a carbon-carbon double bond/C=C\langle mono\rangle unsaturated whereas stearic acid has all single C=C bonds/saturated ✔️</td>
<td></td>
<td>3 max</td>
</tr>
<tr>
<td></td>
<td>ricinoleic acid has an OH-hydroxyl group (in the chain) whereas stearic acid does not ✔️</td>
<td></td>
<td>3 max</td>
</tr>
<tr>
<td>9. b ii</td>
<td>ricinoleic acid more likely to undergo oxidative rancidity (than stearic acid) ✔️</td>
<td></td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>carbon-carbon double bond C=C can be oxidized ✔️</td>
<td></td>
<td>1</td>
</tr>
</tbody>
</table>

Q# 15/ IB Chem/2016/s/TZ0/Paper 3/Higher Level/

<table>
<thead>
<tr>
<th>Question</th>
<th>Answers</th>
<th>Notes</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>8. a i</td>
<td>allyl/methylthiophene ✔️</td>
<td>Award [1] for a sketch of the steroidal backbone.</td>
<td>1</td>
</tr>
<tr>
<td>8. a ii</td>
<td>four-rings steroids backbone OR fused ring structure OR three 5-membered rings AND a 5-membered ring</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>9. b</td>
<td>medical use of steroids under physician supervision OR detection of banned substances can be improved</td>
<td>Accept any specific medical use. Accept answers such as “their effects either positive or negative are better understood”</td>
<td>1</td>
</tr>
</tbody>
</table>
### Q# 16/ IB Chem/2016/w/TZ0/Paper 3/Higher Level/Q12

<table>
<thead>
<tr>
<th>Question</th>
<th>Answers</th>
<th>Notes</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>12. a</td>
<td>( \text{CO}_2 ) AND ( \text{H}_2\text{O} ) AND sun ✓</td>
<td>Accept names. Accept “sunlight/glight/photons” instead of “sun”.</td>
<td>1</td>
</tr>
<tr>
<td>12. b i</td>
<td>both have formula ( \text{C}_2\text{H}_2\text{O}_2 ), OR both contain several ( \text{OH} )hydroxy groups AND a ( \text{C}=\text{O} )carbonyl group ✓</td>
<td>Accept “both have formula ( \text{C}_2\text{H}_2\text{O}_2 )” \text{temporal} formula ( \text{CH}_3\text{O} ) \text{but do not accept “both have same molecular formula have formula } \text{C}_2\text{H}_2\text{O}_2 ). Accept “hydroxy” but not “hydroxide/OH” for “hydroxy”. Accept “aldehyde or ketone” for “carbonyl”.</td>
<td>1</td>
</tr>
<tr>
<td>12. b ii</td>
<td>[Diagram of ( \text{RCHO/CH}_2\text{O} ) OR ( \text{C}=\text{O} )carbonyl group with ( \text{C}=\text{O} ) bonded to ( \text{H} ) OR ( \text{formyl} ) group OR ( \text{C}=\text{O} )carbonyl group at end of chain at ( \text{C}-1 ) endatom] ✓</td>
<td>Accept “alkyl” for “( \text{R} )”. Accept “( \text{C} = \text{O} )” for “aldehyde AND Y ketone/ketone”. Accept “( \text{CO} )” for “( \text{C} = \text{O} )”.</td>
<td>1</td>
</tr>
<tr>
<td>12. c i</td>
<td>[Diagram of ( \text{CH}_2\text{OH} )OH] continuation bonds AND open ( \text{O} ) on either but not both ends ✓</td>
<td>Brackets are not necessary for the mark. Do not accept ( \beta )-isomer. Mark may be awarded if a polymer is shown but with the repeating unit clearly identified. 3D representation is not required.</td>
<td>1</td>
</tr>
<tr>
<td>12. c ii</td>
<td>Advantage: Any one of: biodegradeable / break down naturally by bacteria ✓ compostable ✓ does not contribute to land-fill ✓ renewables/sustainable resource ✓ starch grains saved AND help break up plastic ✓ lower greenhouse gas emissions ✓ uses less fossil fuels than traditional plastics ✓ less energy needed for production ✓ Disadvantage: Any one of: land use affects biodiversity / loss of habitats ✓ growing corn for plastics instead of food ✓ “starch” breakdown can increase acidity of soil/compost ✓ “starch” breakdown can produce methane especially when burned ✓ sensitive to moisture / bacterial attack ✓ bioplastic sometimes degrade quickly/ before end of use cannot be reused poor mechanical strength ✓ eutrophication ✓ increased use of fertilizers/pesticides/phosphorus/nitrogen has negative environmental effects ✓</td>
<td>Ignore any reference to cost. Do not accept just “decompose easily”. Accept “prone to soil explosions” as an alternative for disadvantage. Only award [1 max] if the same example is used for the advantage and disadvantage.</td>
<td>2 max</td>
</tr>
</tbody>
</table>

### Q# 17/ IB Chem/2016/s/TZ0SP/Paper 3/Higher Level/

<table>
<thead>
<tr>
<th>Question</th>
<th>Answers</th>
<th>Notes</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>8. a</td>
<td>[Diagram of ( \text{CH}_3\text{OH} )OH]</td>
<td>Award mark for a correctly placed ( \text{I} ) and a correctly placed ( \text{II} ). Allow ( \text{II} ) placed on hemiacetal.</td>
<td>1</td>
</tr>
<tr>
<td>8. b i</td>
<td>( \text{C}_2\text{H}_2\text{O}_5 \text{H}_2\text{O} \rightarrow 2\text{C}_2\text{H}_2\text{O}_6 ) ✓</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>8. b ii</td>
<td>[Diagram of hydrolysate] catalyzes ✓</td>
<td>Accept hydrolysis.</td>
<td>1</td>
</tr>
</tbody>
</table>

### Q# 18/ IB Chem/2016/s/TZ0/Paper 3/Higher Level/

<table>
<thead>
<tr>
<th>Question</th>
<th>Answers</th>
<th>Notes</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>11. a</td>
<td>( \text{C}_6\text{H}_12\text{O}_6 \text{(aq)} + 6\text{O}_2 \text{(aq)} \rightarrow 6\text{CO}_2 \text{(aq)} + 6\text{H}_2\text{O}(l) ) ✓</td>
<td>Accept equations for anaerobic respiration, such as ( \text{C}_6\text{H}_12\text{O}_6 \text{(aq)} \rightarrow 2\text{C}_2\text{H}_4\text{O}_4 \text{(aq)} ). Ignore ( \text{ATP} ) if added as a product.</td>
<td>1</td>
</tr>
<tr>
<td>11. b</td>
<td>[Diagram of ( \text{C}_6\text{H}_12\text{O}_6 )] ( 150 \degree \text{C} = 180 \text{kJ} )</td>
<td>Award [2] for correct final answer. Accept [223 kJ].</td>
<td>2</td>
</tr>
</tbody>
</table>
Q# 19/ IB Chem/2016/s/TZ0/Paper 3/Higher Level/

<table>
<thead>
<tr>
<th>Question</th>
<th>Answers</th>
<th>Notes</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>13. a</td>
<td>A and D have one or two polar hydroxyl (OH) groups but C has many of those OR A and D have hydroxyl (OH) groups that are attached to a membered ring but C has heteroatomic, hetero-membered rings OR A and D have long hydrocarbon chains of primarily non-polar compounds</td>
<td>Accept other valid similarities or differences. Accept &quot;hydroxylic alcohol&quot; but not &quot;hydroxide&quot; for &quot;hydroxylic&quot;.</td>
<td>1</td>
</tr>
</tbody>
</table>

Q# 20/ IB Chem/2016/s/TZ0SP/Paper 3/Higher Level/

<table>
<thead>
<tr>
<th>Question</th>
<th>Answers</th>
<th>Notes</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>10. a</td>
<td>Substance/chemical/compound found in organism not normally present OR compound foreign to living organism</td>
<td>Accept artificially synthesized/man made compound in the environment/biosphere.</td>
<td>1</td>
</tr>
<tr>
<td>b</td>
<td>non-polar OR lipophilic OR structure based on phenyl/hydrocarbon OR hydrophobic interactions OR similar chemical properties to fat</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>c</td>
<td>ionic bonds OR hydrogen bonds OR van der Waals forces OR hydrophobic interactions</td>
<td>Award [1] for any 3 correct answers. Accept alternate valid answers other than ionic bonding</td>
<td>1 max</td>
</tr>
</tbody>
</table>

Q# 21/ IB Chem/2016/s/TZ0/Paper 3/Higher Level/

<table>
<thead>
<tr>
<th>Question</th>
<th>Answers</th>
<th>Notes</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>11. c</td>
<td>Two advantages: renewable resource OR broken down digested by bacteria or other organisms within a relatively short time OR reduce volume of plastic waste/landfill OR reduce use of petroleum OR reduce use of fossil fuels as hydrocarbon source OR degrade into non-toxic products OR Two disadvantages: require use of land for crop production OR increased use of fertilizers/pesticides leading to pollution OR eutrophication OR might break down before end of use OR release of methane/CH4 from greenhouse gas during degradation</td>
<td>Any two advantages for (2 max).</td>
<td>4 max</td>
</tr>
</tbody>
</table>

Q# 22/ IB Chem/2016/w/TZ0/Paper 3/Higher Level/Q14

<table>
<thead>
<tr>
<th>Question</th>
<th>Answers</th>
<th>Notes</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>14. a I</td>
<td>$K_w$, herokinsase approx. 1.7 10^-14 mmol dm^-3 OR $K_w$, glucokinase approx. 0.5 10^-14 mmol dm^-3</td>
<td>Accept answers in the range 1.0-2.0 for herokinsase and 0.5-1.0 for glucokinase.</td>
<td>1</td>
</tr>
<tr>
<td>14. a II</td>
<td>glucokinase as it is not saturated with substrate at normal concentration of blood glucose OR glucokinase as its saturation increases with increased glucose concentration in the blood</td>
<td>Accept &quot;at the normal levels of blood glucose concentration, relative velocity of glucokinase still dependent on concentration of glucose&quot;.</td>
<td>1</td>
</tr>
<tr>
<td>14. b I</td>
<td>glucose-6-phosphate lowers enzyme activity OR acts as enzyme inhibitor</td>
<td>Accept &quot;outside/away from active site&quot;.</td>
<td>1</td>
</tr>
<tr>
<td>14. b II</td>
<td>inhibitor binds at allosteric site</td>
<td></td>
<td>1</td>
</tr>
</tbody>
</table>

Q# 23/ IB Chem/2016/w/TZ0/Paper 3/Higher Level/Q13

<table>
<thead>
<tr>
<th>Question</th>
<th>Answers</th>
<th>Notes</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>13. a</td>
<td>2-amino-4-methylpentanoic acid</td>
<td>Accept &quot;4-methyl-2-amino-pentanoic acid&quot;.</td>
<td>1</td>
</tr>
<tr>
<td>b</td>
<td>$\text{pH} = -\log [\text{HA}] / (\text{HA})$ OR $\text{pH} = -\log [\text{COOH}] / (\text{COOH})$ OR $10^{-1} = [\text{COOH}] / [\text{COOH}]$</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>c</td>
<td>$%\text{percentage ionized} = \frac{1}{1 + 10^x}$</td>
<td>Award [3] for correct final answer.</td>
<td>3</td>
</tr>
</tbody>
</table>
Q# 24/ IB Chem/2016/s/TZoSP/Paper 3/Higher Level/Q8

<table>
<thead>
<tr>
<th>Question</th>
<th>Answers</th>
<th>Notes</th>
<th>Total</th>
</tr>
</thead>
</table>
| 8. d     | \[\text{pH} = \text{pK}_a + \log \left(\frac{[A^-]}{[HA]}\right)\] butanoic acid \(\text{pK}_a = 4.839\)  
\[5.00 - 4.83 = \log \frac{[\text{butanoate ion}]}{0.10}\] OR  
\[10^{-1.17} = \frac{[\text{butanoate ion}]}{0.10} = 1.479\]  
\[\text{[butanoate ion]} = 0.1479 \text{mol dm}^{-3}\]  
if \(1.00 \text{dm}^3 \times 0.10 \text{mol dm}^{-3}\) butanoic acid  
\(1.00 \text{dm}^3 \times 0.1479 \text{mol dm}^{-3} = 110.91 \text{g mol}^{-1}\) solution: 110.91 g mol\(^{-1}\)  
\(\text{sodium butanoate}\)  
| Accept alternate valid methods. | 3 |

Q# 25/ IB Chem/2016/s/TZ0/Paper 3/Higher Level/

<table>
<thead>
<tr>
<th>Question</th>
<th>Answers</th>
<th>Notes</th>
<th>Total</th>
</tr>
</thead>
</table>
| 12. a    | Graph showing competitive inhibitor eventually reaching \(V_{max}\) ✓  
Graph showing non-competitive inhibitor not reaching \(V_{max}\) ✓  
\(2.10 \times 10^{-8} \text{mol L}^{-1}\)  
\(3.00 \times 10^{-8} \text{mol L}^{-1}\)  
\(0.153\) ✓  
\(4.86 - 2.08 = 2.80\) ✓  
\(1.13\) ✓  
<br>**Curves must be labelled and should not cross given curve.**  
**Penalize one mark if one or both sketched curve(s) cross the given curve.**  
**Award [1 max] if curves are not labelled competitive or non-competitive OR are labelled the wrong way round.** | 2 |
| 12. b    | Allow hydrogen bonds between \(A\) and \(C\) and \(G\). | 2 |

Q# 26/ IB Chem/2016/w/TZ0/Paper 3/Higher Level/Q15

<table>
<thead>
<tr>
<th>Question</th>
<th>Answers</th>
<th>Notes</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>15. a</td>
<td>phosphate/polyphosphate &amp;group ✓</td>
<td>Do not accept “phosphoric acid”, “phosphorus” or any formula.</td>
<td>1</td>
</tr>
</tbody>
</table>
| 15. b    | mass spectrometry / X ray diffraction/crystallography / nuclear magnetic resonance spectroscopy OR  
bacteria able to grow in absence of phosphorus OR  
reproducible data ✓ | Accept abbreviations (eg, MS, NMR).  
Accept “elemental analysis” or “atomic absorption spectroscopy”  
AA(S). | 1 |

Q# 27/ IB Chem/2016/s/TZoSP/Paper 3/Higher Level/

<table>
<thead>
<tr>
<th>Question</th>
<th>Answers</th>
<th>Notes</th>
<th>Total</th>
</tr>
</thead>
</table>
| 11. a    | phosphate groups negatively charged/anionic to repulsion when close together/stacked OR  
negative charged/hydrophilic phosphate groups associate with aqueous exterior/surface ✓  

<table>
<thead>
<tr>
<th>OWTIE</th>
</tr>
</thead>
</table>

| non-polar bases hydrophobic/non-polar will not easily associate with aqueous exterior/surface OR  
non-polar groups form hydrophobic/non-polar internal environment ✓  
<br>**OWTIE**| 2 |
| 11. b    | hydrogen bonds between paired/complementary bases ✓ | Allow hydrogen bonds between \(A\) and \(T\) and \(C\) and \(G\). | 1 |

Q# 28/ IB Chem/2016/w/TZ0/Paper 3/Higher Level/Q16

<table>
<thead>
<tr>
<th>Question</th>
<th>Answers</th>
<th>Notes</th>
<th>Total</th>
</tr>
</thead>
</table>
| 18. a    | \(\text{**extensive**} \text{ conjugation of double bonds} \text{& delocalization of electrons} \) OR  
\(\text{alternating single/C-C AND double/multiple/C=C bonds ✓} \) | Accept “polar/charged” for “hydroxide” OR  
Do not accept “OH”/hydroxide/ oxygen. | 1 |
| 18. b    | In aqueous solution \(\text{AND} \text{ hydroxide/\text{OH/oxonium/}O-} \) groups ✓ | 1 |

<table>
<thead>
<tr>
<th>Question</th>
<th>Answers</th>
<th>Notes</th>
<th>Total</th>
</tr>
</thead>
</table>
| 16. c    | \(\text{pH} 2: \text{absorption peak} 520 \text{nm red AND} \text{ pH} 11: \text{absorption peak} 620 \text{nm blue ✓} \)  
complementary/opposite colour observed to wavelength absorbed OR  
\(\text{pH} 2: \text{absorption peak} 520 \text{nm green absorbed AND} \text{ pH} 11: \text{absorption peak} 620 \text{nm orange absorbed ✓} \) | Award [1 max] if colour absorbed and colour observed are correct for either at \(\text{pH} 2\) or \(\text{pH} 11\). | 2 |
Q# 29/ IB Chem/2016/s/TZoSP/Paper 3/Higher Level/

<table>
<thead>
<tr>
<th>Question</th>
<th>Answers</th>
<th>Notes</th>
<th>Total</th>
</tr>
</thead>
</table>
| 12. a    | binding to the first polypeptide causes a conformational/3D change in shape ✓  
facilitates the binding to the other polypeptides OR  
cooperative binding ✓ | | 2 |
| b i      | ![Graph](image)  
curve of same shape to the right of given graph ✓ | | 1 |
| b ii     | respiration releases CO₂  
OR  
high concentration of CO₂ near actively respiring cells ✓
percentage saturation of hemoglobin is lower as CO₂ increases  
OR  
hemoglobin lower affinity binds less to oxygen at higher CO₂  
or hemoglobin dissociates more easily/releases O₂ at higher CO₂ ✓ | | 2 |

Q# 30/ IB Chem/2016/s/TZ0/Paper 3/Higher Level/

<table>
<thead>
<tr>
<th>Question</th>
<th>Answers</th>
<th>Notes</th>
<th>Total</th>
</tr>
</thead>
</table>
| 14. a    | low CO₂ level causes more oxygen to be bound to the heme ✓  
high pH causes more oxygen to be bound to the heme ✓  
low temperature causes more oxygen to be bound to the heme ✓  
onorganic phosphates/2,3-BPG/DPG can decrease affinity for oxygen ✓  
CO₂ decreases saturation/binds to active site as a competitive inhibitor ✓ | Accept reverse statements for mark. Award 2 if the effects of CO₂ AND pH are discussed in combination. | 3 max |
| 14. b    | contains two gamma units instead of the two beta units found in adults  
differ in amino acid sequence from the two beta units found in adults ✓  
less sensitive to inhibitors/2,3-BPG/DPG ✓  
receives O₂ from partly deoxygenated blood so can work at low pO₂ ✓ | Accept reverse statements for mark. | 2 max |

Q# 31/ IB Chem/2016/s/TZ0/Paper 3/Higher Level/

<table>
<thead>
<tr>
<th>Question</th>
<th>Answers</th>
<th>Notes</th>
<th>Total</th>
</tr>
</thead>
</table>
| 10. c i  | ![Molecule](image)  
and  
H₂N⁻CH⁻C⁻H⁻O⁻ | Accept un-ionized or zwitterionic forms. Accept any other correct representation which clearly indicates 3-dimensional structure at chiral centre. Accept Fischer projections with the chiral carbon atom represented by crossing lines or shown as C. | 1 |
| 10. c ii | ![Molecule](image)  
and  
H₂N⁻CH⁻C⁻H⁻O⁻ | | 1 |