Diploma Programme
Programme du diplôme
Programa del Diploma

Chemistry
Standard level
Paper 3

Thursday 14 November 2019 (morning)

Candidate session number

1 hour

Instructions to candidates

- Write your session number in the boxes above.
- Do not open this examination paper until instructed to do so.
- Answers must be written within the answer boxes provided.
- A calculator is required for this paper.
- A clean copy of the **chemistry data booklet** is required for this paper.
- The maximum mark for this examination paper is **[35 marks]**.

Section A	Questions
Answer all questions.	1 – 2

Section B	Questions
Answer all of the questions from one of the options.	
Option A — Materials	3 – 6
Option B — Biochemistry	7 – 10
Option C — Energy	11 – 14
Option D — Medicinal chemistry	15 – 19

23 pages

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Section A

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

1.   A student investigated how the type of acid in acid deposition affects limestone, a building
     material mainly composed of calcium carbonate.

	Solubility
calcium carbonate	insoluble
calcium nitrate	soluble
calcium sulfate	slightly soluble

The student monitored the mass of six similarly sized pieces of limestone. Three were placed
in beakers containing $200.0 \, cm^3$ of $0.100 \, mol \, dm^{-3}$ nitric acid, $HNO_3 \, (aq)$, and the other three
in $200.0 \, cm^3$ of $0.100 \, mol \, dm^{-3}$ sulfuric acid, $H_2SO_4 \, (aq)$.
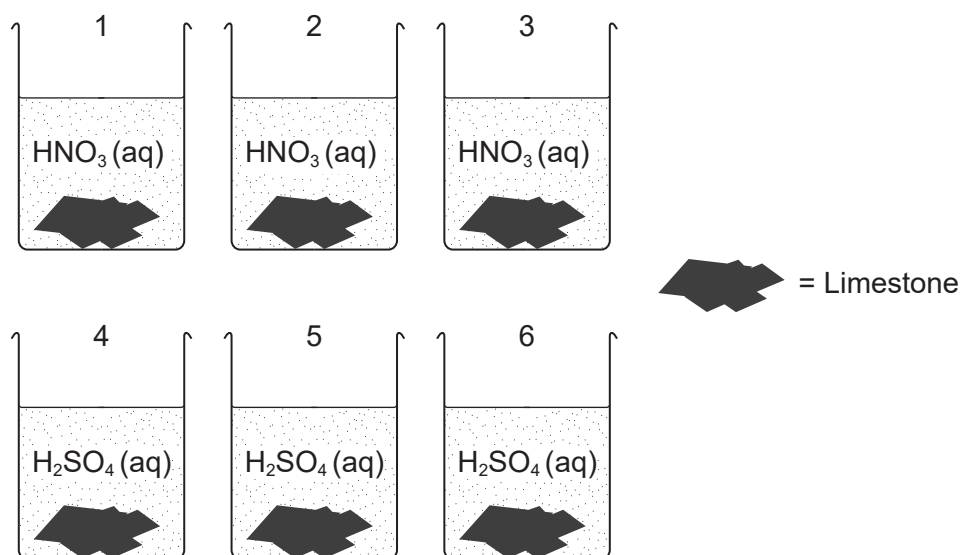
[Source: © International Baccalaureate Organization 2019]

(This question continues on the following page)

(Question 1 continued)

The limestone was removed from the acid, washed, dried with a paper towel and weighed every day at the same time and then replaced in the beakers.

The student plotted the mass of one of the pieces of limestone placed in nitric acid against time.
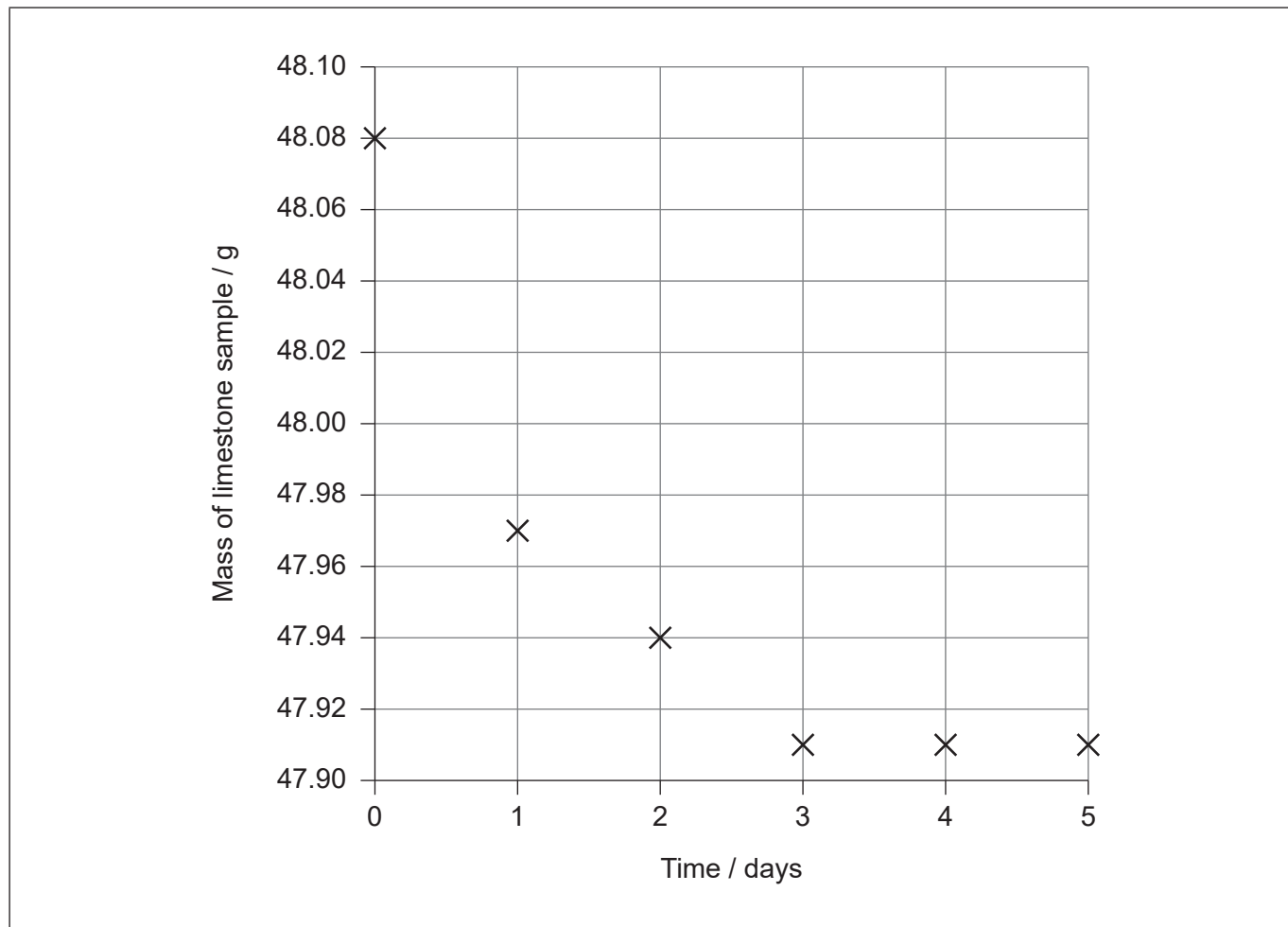
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(a)   Draw a best-fit line on the graph.   [1]

(b)   (i)   Determine the initial rate of reaction of limestone with nitric acid from the graph.
               Show your working on the graph and include the units of the initial rate.   [3]

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(This question continues on page 5)

Please **do not** write on this page.

Answers written on this page
will not be marked.

(Question 1 continued)

      (ii)   Explain why the rate of reaction of limestone with nitric acid decreases and reaches zero over the period of five days. [2]

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      (iii)   Suggest a source of error in the procedure, assuming no human errors occurred and the balance was accurate. [1]

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    (c)   The student hypothesized that sulfuric acid would cause a larger mass loss than nitric acid.

      (i)   Justify this hypothesis. [1]

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      (ii)   The student obtained the following total mass losses.

Acid	Nitric acid			Sulfuric acid		
Limestone sample	1	2	3	4	5	6
Total mass loss / g	0.17	0.14	0.15	0.10	0.07	0.08

          She concluded that nitric acid caused more mass loss than sulfuric acid, which did not support her hypothesis.

          Suggest an explanation for the data, assuming that no errors were made by the student. [1]

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2. Ethanol was electrolysed at different voltages. The products at the anode, ethanoic acid, ethanal and carbon dioxide, were collected and analysed.

The percentages of products obtained using three different catalysts mounted on a carbon anode, platinum (Pt/C), platinum and ruthenium alloy (PtRu/C) and platinum and tin alloy (PtSn/C) are shown.
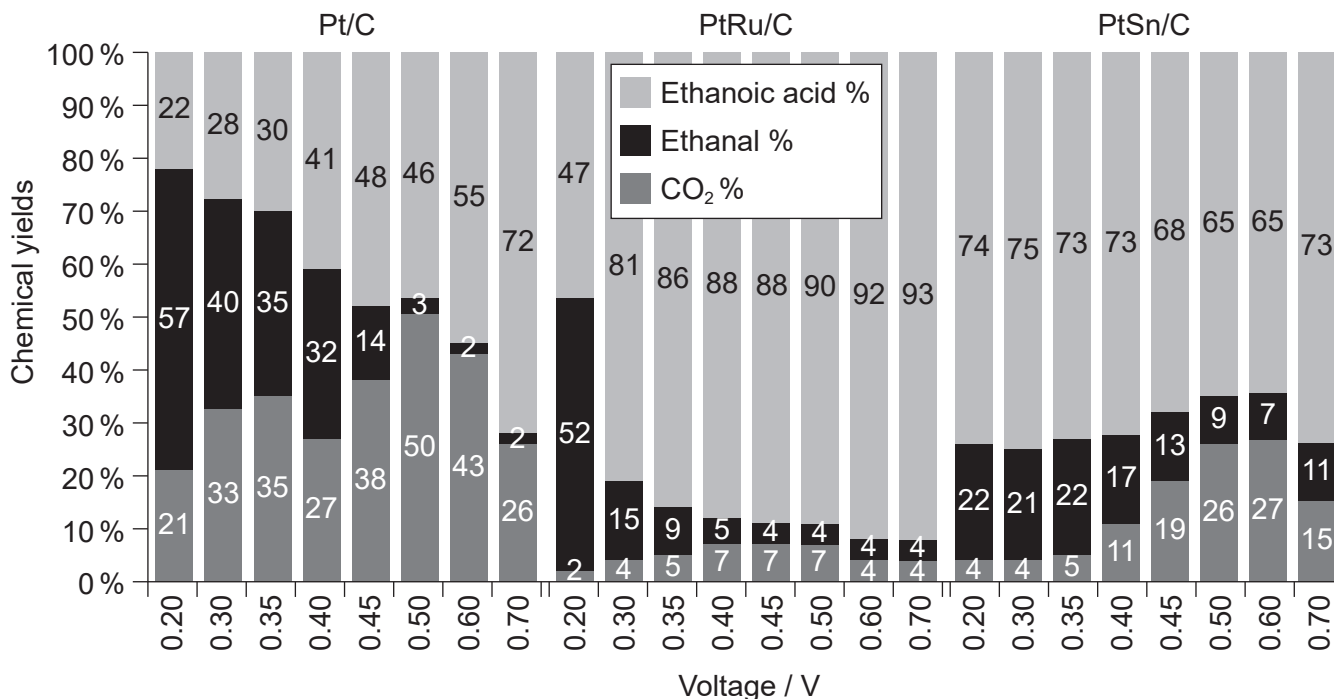
Chemical yields of ethanoic acid, ethanal and carbon dioxide as a function of voltage for oxidation of $0.100 \, mol \, dm^{-3}$ ethanol at Pt/C, PtRu/C and PtSn/C anodes at $80\,°C$.

(a) (i) Describe the effect of increasing the voltage on the chemical yield of: [2]

Ethanal using Pt/C:

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Carbon dioxide using PtRu/C:

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(This question continues on the following page)

(Question 2 continued)

       (ii)   Determine the change in the average oxidation state of carbon. [2]

From ethanol to ethanal:

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From ethanol to carbon dioxide:

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       (iii)   List the three products at the anode from the least to the most oxidized. [1]

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(b)   Deduce, giving your reason, which catalyst is most effective at fully oxidizing ethanol. [1]

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Section B

Answer **all** of the questions from **one** of the options. Answers must be written within the answer boxes provided.

Option A — Materials

3. Catalysts are commonly used in industry.

    (a) Describe how a heterogeneous catalyst provides an alternative pathway for a reaction.   [2]

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    (b) Distinguish between heterogeneous and homogeneous catalysts, giving **one** difference.   [1]

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    (c) Nanotubes are used to support the active material in nanocatalysts.

    Explain why oxygen cannot be used for the chemical vapour deposition (CVD) preparation of carbon nanotubes.   [2]

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(Option A continues on the following page)

(Option A continued)

4. Polypropene is used to make many objects including carpets, stationery and laboratory equipment.

   (a) Draw a section of an isotactic polypropene polymer chain containing four repeating units.   [1]

   (b) Predict, with a reason, whether isotactic or atactic polypropene has the higher melting point.   [1]

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   (c) Polypropene is a thermoplastic. Outline what is meant by thermoplastic.   [1]

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   (d) Discuss why the recycling of plastics is an energy intensive process.   [2]

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(Option A continues on the following page)

(Option A continued)

5. Metals are extracted from their ores by various means.

(a) Discuss why different methods of reduction are needed to extract metals. [2]

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(b) Aluminium is produced by the electrolysis of alumina (aluminium oxide) dissolved in cryolite.

(i) Determine the percentage of ionic bonding in alumina using sections 8 and 29 of the data booklet. [2]

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(Option A continues on the following page)

(Option A, question 5 continued)

(ii) Write half-equations for the electrolysis of molten alumina using graphite electrodes, deducing the state symbols of the products. [3]

	Melting point / K
Alumina	2345
Cryolite	1285
Aluminium	933
Graphite	3500

Anode (positive electrode):

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Cathode (negative electrode):

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6. A soap solution can form a liquid-crystal state.

(a) Describe the arrangement of soap molecules in the nematic liquid crystal phase. [2]

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(b) State how liquid crystals are affected by an electric field. [1]

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End of Option A

Turn over

Option B — Biochemistry

7. Aspartame is formed from the two amino acids aspartic acid (Asp) and phenylalanine (Phe).

(a) Draw the structure of the dipeptide Asp–Phe using section 33 of the data booklet. [2]

(b) The isoelectric point of amino acids is the intermediate pH at which an amino acid is electrically neutral.

Suggest why Asp and Phe have different isoelectric points. [2]

(Option B continues on the following page)

(Option B continued)

8. Enzymes are biological catalysts.

(a) The graph shows the relationship between the temperature and the rate of an enzyme-catalysed reaction.
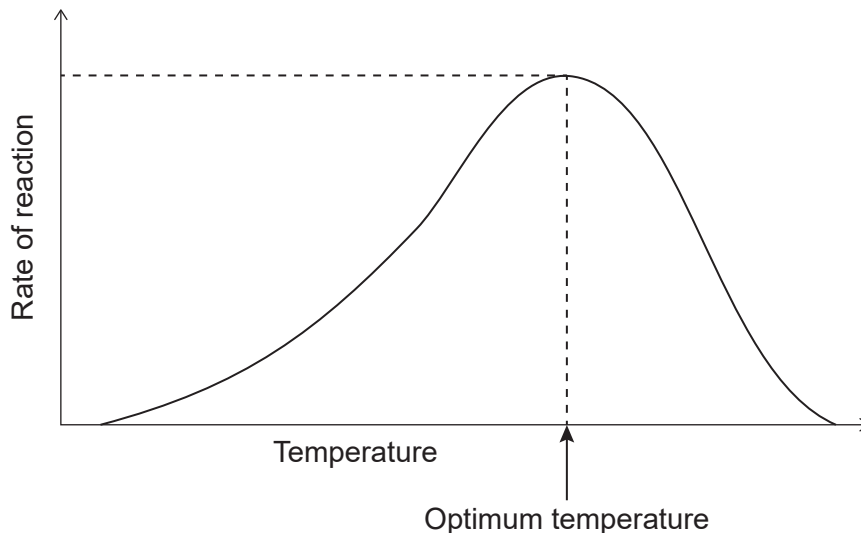
[Source: © International Baccalaureate Organization 2019]

State **one** reason for the decrease in rate above the optimum temperature. [1]

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(b) Explain why a change in pH affects the tertiary structure of an enzyme in solution. [2]

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(c) State **one** use of enzymes in reducing environmental problems. [1]

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(Option B continues on the following page)

(Option B continued)

9.   Stearic acid ($M_r = 284.47$) and oleic acid ($M_r = 282.46$) have the same number of carbon atoms. The structures of both lipids are shown in section 34 of the data booklet.

(a)   The iodine number is the number of grams of iodine which reacts with 100 g of fat. Calculate the iodine number of oleic acid.   [1]

(b)   State **one** impact on health of the increase in LDL cholesterol concentration in blood.   [1]

(c)   Explain why stearic acid has a higher melting point than oleic acid.   [2]

(d)   (i)   State **one** similarity and **one** difference in composition between phospholipids and triglycerides.   [2]

Similarity:

Difference:

(Option B continues on the following page)

(Option B, question 9 continued)

(ii)   Identify a reagent that hydrolyses triglycerides.   [1]

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10.   (a)   Vitamins are organic compounds essential in small amounts.

State the name of **one** functional group common to all three vitamins shown in section 35 of the data booklet.   [1]

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(b)   Explain the biomagnification of the pesticide DDT.   [2]

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(c)   Explain why maltose, $C_{12}H_{22}O_{11}$, is soluble in water.   [2]

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End of Option B

Turn over

Option C — Energy

11.   Consider the following data for butane and pentane at STP.

	Specific energy / $MJ\,kg^{-1}$	Energy density / $MJ\,m^{-3}$
Butane	49.5	128
Pentane	48.6	30 400

   (a)   Discuss the data.   [3]

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   (b)   In a natural gas power station, 1.00 tonne of natural gas produces $2.41 \times 10^4\,MJ$
         of electricity.

         Calculate the percentage efficiency of the power station.

         1 tonne $= 1000\,kg$
         Specific energy of natural gas used $= 55.4\,MJ\,kg^{-1}$ [2]

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(Option C continues on the following page)

(Option C continued)

12. Octane number is a measure of the performance of engine fuel.

(a) Suggest why a high-octane number fuel is preferable. [1]

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(b) (i) Reforming reactions are used to increase the octane number of a hydrocarbon fuel.

Suggest the structural formulas of **two** possible products of the reforming
reaction of heptane, C_7H_{16}. [2]

(ii) The ^1H NMR spectrum of one of the products has four signals. The integration
trace shows a ratio of the areas under the signals of $9:3:2:2$.

Deduce the structural formula of the product. [1]

(Option C continues on the following page)

(Option C continued)

13. Red supergiant stars contain carbon-12 formed by the fusion of helium-4 nuclei with beryllium-8 nuclei.

Mass of a helium-4 nucleus = 4.002602 amu
Mass of a beryllium-8 nucleus = 8.005305 amu
Mass of a carbon-12 nucleus = 12.000000 amu

(a) (i) State the nuclear equation for the fusion reaction. [1]

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(ii) Explain why fusion is an exothermic process. [2]

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(b) Beryllium-8 is a radioactive isotope with a half-life of 6.70×10^{-17} s.

Calculate the mass of beryllium-8 remaining after 2.01×10^{-16} s from a sample initially containing 4.00 g of beryllium-8. [2]

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(Option C continues on the following page)

(Option C continued)

14. Ethanol is a biofuel that can be mixed with gasoline.

(a) Write the equation for the complete combustion of ethanol. [1]

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(b) Outline the evidence that relates global warming to increasing concentrations of greenhouse gases in the atmosphere. [2]

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(c) Explain, including a suitable equation, why biofuels are considered to be carbon neutral. [2]

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(d) State the type of reaction that occurs when ethanol reacts with vegetable oil to form biodiesel. [1]

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End of Option C

Option D — Medicinal chemistry

15. Codeine, morphine and diamorphine (heroin) are derived from opium.

(a) State the names of **two** functional groups present in all three molecules, using section 37 of the data booklet. [2]

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(b) Explain why diamorphine has greater potency than morphine. [3]

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16. Body fluids have different pH values.

(a) Identify the compound responsible for the acidity of gastric juice, and state whether it is a strong or weak acid. [1]

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(b) An antacid contains calcium carbonate and magnesium carbonate.

Write the equation for the reaction of magnesium carbonate with excess stomach acid. [1]

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(Option D continues on the following page)

(Option D, question 16 continued)

(c)   Outline how ranitidine reduces stomach acidity.   [1]

(d)   Calculate the pH of a buffer solution which contains $0.20\,mol\,dm^{-3}$ ethanoic acid and $0.50\,mol\,dm^{-3}$ sodium ethanoate. Use section 1 of the data booklet.
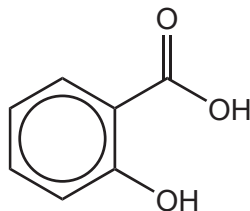
   pK_a (ethanoic acid) $= 4.76$ [1]

17.   The structure of aspirin is shown in section 37 of the data booklet.

Salicylic acid

(a)   Suggest **one** reactant used to prepare aspirin from salicylic acid.   [1]

(Option D continues on the following page)

(Option D, question 17 continued)

(b)   Aspirin, $C_6H_4(OCOCH_3)COOH$, is only slightly soluble in water.

Outline, including an equation, how aspirin can be made more water-soluble. Use section 37 in the data booklet.   [2]

18.   Infectious diseases can be caused by bacteria or viruses.

(a)   State **one** difference between bacteria and viruses.   [1]

(b)   Discuss **two** difficulties, apart from socio-economic factors, associated with finding a cure for AIDS.   [2]

(Option D continues on the following page)

(Option D, question 18 continued)

(c) The discovery of penicillins contributed to the development of antibiotics.

Explain how the beta-lactam ring is responsible for the antibiotic properties of penicillin. Refer to section 37 of the data booklet. [3]

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19. Disposal of chemical waste is a growing problem in industry.

(a) Outline the impact of antibiotic waste on the environment. [1]

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(b) Suggest a concern about the disposal of solvents from drug manufacturing. [1]

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End of Option D

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