Diploma Programme
Programme du diplôme
Programa del Diploma

Chemistry
Standard level
Paper 3

Friday 13 May 2016 (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.
- Section A: answer all questions.
- Section B: answer all of the questions from one of the options.
- Write your answers in the 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]**.

Option	Questions
Option A — Materials	3 – 7
Option B — Biochemistry	8 – 10
Option C — Energy	11 – 15
Option D — Medicinal chemistry	16 – 19

2216 – 6106

26 pages

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

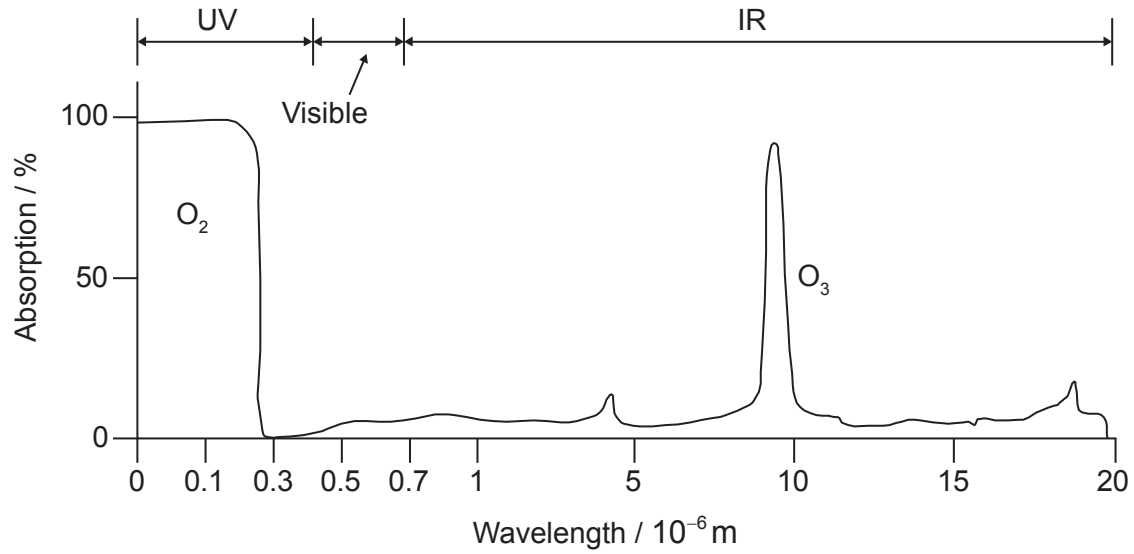
Answers written on this page
will not be marked.

Section A

Answer **all** questions.

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

Graph of IR absorbances for oxygen and ozone molecules



[Source: adapted from 2007 Thomson Higher Education, www.acs.org]

(a) Using the graph, state, giving your reasons, whether or not oxygen and ozone are greenhouse gases. [2]

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(This question continues on the following page)

(Question 1 continued)

(b) The following data has been compiled for a range of molecules that may be found in the atmosphere.

Molecule	Integrated IR intensity* / km mol^{-1}	Molecular dipole moment / Debyes	GWP** over 100 years
CO_2	25.7	0	1
CCl_4	443.7	0	1400
CCl_3F	705.2	0.45	4750
CCl_2F_2	970.1	0.51	10900
$CClF_3$	1199	0.50	14400
CF_4			

[Sources: "Identifying the Molecular Origin of Global Warming", Partha P Bera, Joseph S Francisco and Timothy J Lee. Published in J. Phys. Chem. A, Vol. 113, No. 45, 2009 and accessed from www.r744.com]

*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 CO_2, which has a GWP of 1.

(i) Use the integrated IR intensity data in the table to estimate the value for CF_4. [1]

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(ii) Explain the increase in molecular dipole moment as one chlorine atom in CCl_4 is replaced with fluorine to produce CCl_3F. [2]

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(This question continues on the following page)

(Question 1 continued)

(iii) Outline the relationship between GWP over 100 years and integrated IR intensity for CCl_4, CCl_3F, CCl_2F_2 and $CClF_3$. [1]

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(iv) Examine whether there is a general relationship between integrated IR intensity and molecular dipole moment. [1]

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(v) CCl_2F_2 and $CClF_3$ 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. [2]

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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 dm^3 aqueous solution.

20.0 cm^3 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 dm^3 aqueous solution from the 4.00 g sodium hydroxide pellets. [2]

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(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]

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(ii) The student added the acid too quickly. Outline, giving your reason, how this could have affected the calculated concentration. [2]

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(This question continues on the following page)

(Question 2 continued)

(c) Suggest why, despite preparing the solution and performing the titrations very carefully, widely different results were obtained. [1]

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Section B

Answer **all** of the questions from **one** of the options.

Option A — Materials

3. Iron may be extracted from an ore containing Fe_2O_3 in a blast furnace by reaction with coke, limestone and air. Aluminium is obtained by electrolysis of an ore containing Al_2O_3.

(a) State the overall redox equation when carbon monoxide reduces Fe_2O_3 to Fe. [1]

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(b) Predict the magnetic properties of Fe_2O_3 and Al_2O_3 in terms of the electron structure of the metal ion, giving your reasons. [2]

Fe_2O_3:

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Al_2O_3:

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(Option A continues on the following page)

(Option A, question 3 continued)

(c) Molten alumina, $Al_2O_3(l)$, was electrolysed by passing 2.00×10^6 C through the cell. Calculate the mass of aluminium produced, using sections 2 and 6 of the data booklet. [2]

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4. Nanocatalysts have large surface areas per unit mass.

(a) Identify **one** concern of using nanoscale catalysts. [1]

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(b) Explain how zeolites act as selective catalysts. [2]

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(Option A continues on the following page)

(Option A, question 4 continued)

(c) Carbon nanotubes, which can be produced by the HIPCO process, show great potential as nanocatalysts. Identify the catalyst and conditions used in the HIPCO process. [2]

Catalyst:

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Conditions:

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5. Describe how the structures of ceramics differ from those of metals. [2]

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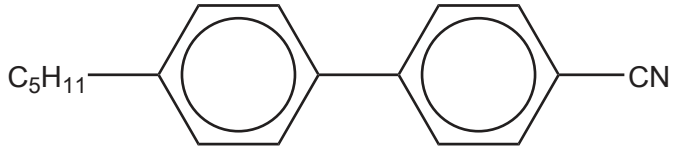
(Option A continues on the following page)

(Option A continued)

6. Biphenyl nitriles, such as the molecule shown below, were the first thermotropic liquid crystal molecules to be synthesized.



(a) Suggest how changing the size or shape of the hydrocarbon chain would affect the molecule's liquid crystal behaviour. [1]

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(b) Explain why the nitrile group enables these molecules to be used in liquid-crystal displays (LCDs). [2]

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7. Chloroethene undergoes polymerization with a free-radical initiator to produce the atactic form of polychlorethene (PVC).

(a) Sketch the atactic form of polychloroethene showing **four** units. [1]

(Option A continues on the following page)

(Option A, question 7 continued)

(b) (i) Explain, in molecular terms, why PVC becomes more flexible and softer when a plasticizer is added. [2]

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(ii) State **one** type of compound which can be used as a plasticizer. [1]

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(c) Suggest an environmental issue associated with the use of PVC. [1]

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End of Option A

Option B — Biochemistry

8. Dehydroepiandrosterone (DHEA) is a substance banned under the World Anti-Doping Code.

(a) Steroid abuse has certain health hazards, some general, some specific to males and some specific to females. Identify **one** health hazard in **each** category. [3]

General hazard:

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Male hazard:

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Female hazard:

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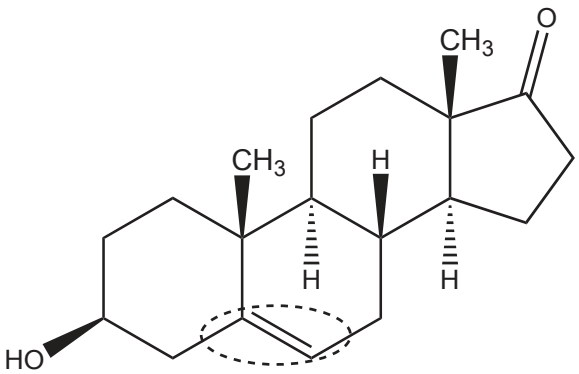
(b) (i) State the name of the functional group circled in the DHEA molecule shown below. [1]



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(Option B continues on the following page)

(Option B, question 8 continued)

(ii) Identify the characteristic of this structure that classifies it as a steroid. [1]

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(c) The production of banned steroids has ethical implications. Suggest a reason why steroid research might be supported. [1]

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9. 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. [3]

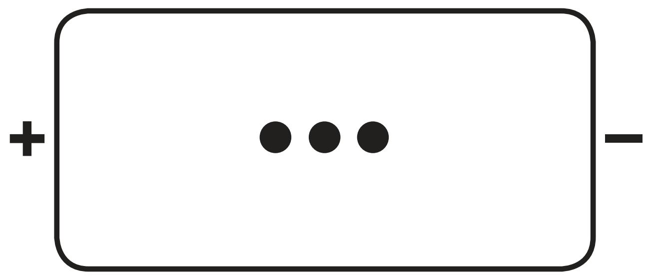
pH 1.0	pH 6.0	pH 11.0

(Option B continues on the following page)

(Option B, question 9 continued)

(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. [2]



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(ii) Deduce the number of tripeptides that could be formed by using the three amino acids of tripeptide **X**. [1]

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(Option B continues on the following page)

(Option B continued)

10. Glucose, $C_6H_{12}O_6$, is a monosaccharide that our body can use as a source of energy.

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

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(b) Calculate the energy, in kJ, produced from 15.0 g of glucose if its enthalpy of combustion is $-2803\,kJ\,mol^{-1}$. [2]

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(c) Glucose is the basic building block of starch which can be used to make bioplastics. Outline **two** advantages and **two** disadvantages of biodegradable plastics. [4]

Two advantages:

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Two disadvantages:

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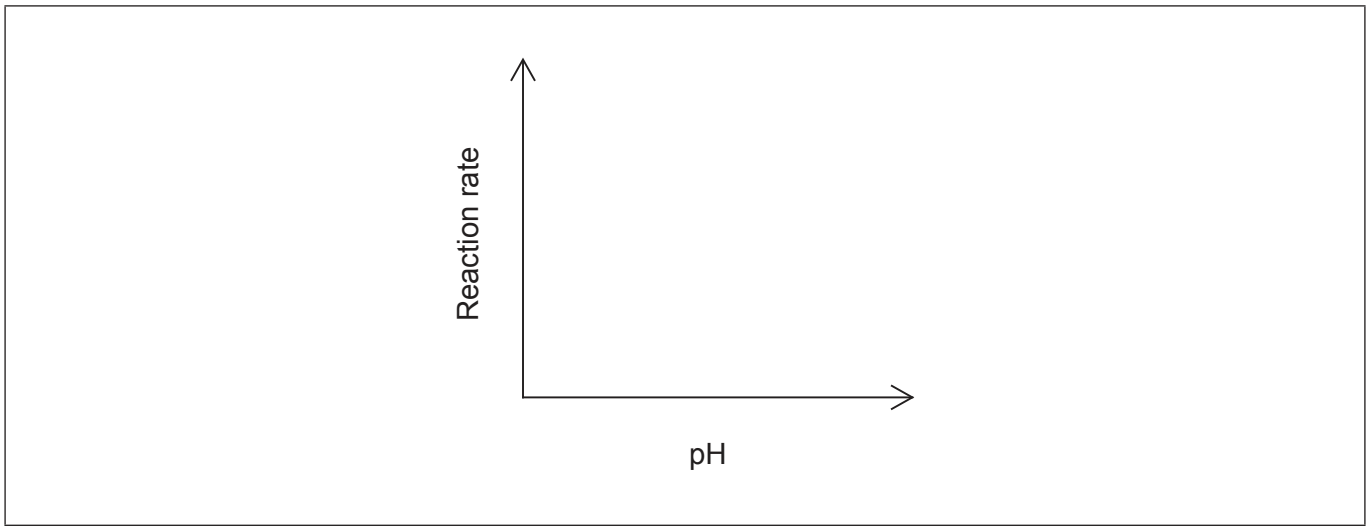
(Option B continues on the following page)

(Option B, question 10 continued)

(d) Bioplastics are broken down by enzyme catalysed reactions. Sketch a graph illustrating how the rate of this reaction varies with pH. [1]



End of Option B

Option C — Energy

11. Hexane, C_6H_{14}, is not a suitable fuel for internal combustion engines as it has a tendency to auto-ignite, a cause of "knocking".

(a) (i) Hexane can be converted to different organic products in a reforming process. Identify **one** of these products. [1]

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(ii) Suggest why the product in (a)(i) has a lesser tendency to auto-ignite than hexane. [1]

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(b) (i) Octane, C_8H_{18}, can undergo complete combustion under suitable conditions. Calculate the specific energy of octane, in $kJ\,g^{-1}$, using sections 1, 6 and 13 of the data booklet. [1]

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(Option C continues on the following page)

(Option C, question 11 continued)

(ii) The specific energy of ethanol is $29.7\,kJ\,g^{-1}$. Evaluate the addition of ethanol to octane (or its isomers) for use as a fuel in motor vehicles, giving **one** advantage and **one** disadvantage. [2]

Advantage:

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Disadvantage:

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(c) Coal can be heated with steam to produce synthetic natural gas. Formulate an equation to show the formation of methane, $CH_4(g)$, from coal, $C(s)$, and steam, $H_2O(g)$. [1]

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12. Vegetable oils and diesel fuel have similar energy content but vegetable oils are not usually used as fuels in internal combustion engines.

(a) Transesterification reactions allow waste cooking oils to be converted to biofuels. Identify a reagent and catalyst required for this conversion. [2]

Reagent:

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Catalyst:

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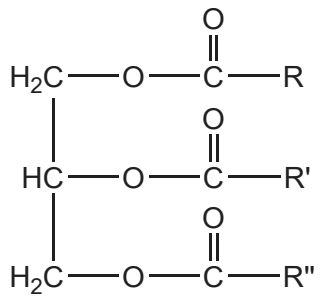
(Option C continues on the following page)

(Option C, question 12 continued)

(b) Deduce the equation for the reaction that occurs assuming that the vegetable oil has the formula drawn below. [2]



(c) Scientists around the world conduct research into alternatives to fossil fuels. Suggest why collaboration is important. [1]

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13. Fusion and fission reactions are important nuclear reactions.

(a) Curium, ^{240}Cm, was synthesized by bombarding thorium nuclei, ^{232}Th, with carbon-12 nuclei. State a balanced equation for this reaction. [1]

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(Option C continues on the following page)

(Option C, question 13 continued)

(b) Uranium-235 has a half-life of 7.038×10^8 years.

(i) Determine the time required for the mass of ^{235}U in a sample originally containing 1.000 g of ^{235}U to decrease to 0.125 g. [1]

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(ii) Outline why products of the fission of uranium-235 must be disposed of carefully. [1]

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(c) Outline why an element such as thorium, Th, usually undergoes nuclear fission, whereas helium, He, undergoes nuclear fusion. [1]

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14. Atmospheric carbon dioxide and aqueous carbon dioxide in the oceans form a heterogeneous equilibrium.

Explain the effect of increasing concentrations of atmospheric carbon dioxide on the pH of the oceans, including an equation in your answer. [3]

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(Option C continues on the following page)

(Option C continued)

15. Carbon dioxide, CO_2, is a greenhouse gas. Outline, in molecular terms, how carbon dioxide molecules absorb infrared radiation. [2]

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End of Option C

Option D — Medicinal chemistry

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

(a) Explain the importance of the beta-lactam ring in the antibiotic activity of penicillin. [3]

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(b) Identify **two** dangers of the overuse of antibiotics. [1]

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17. Opiates have been used for thousands of years to alleviate pain. The structures of opiates are found in section 37 of the data booklet.

(a) Diamorphine (heroin) can be synthesized from morphine. Identify the reagent necessary for this reaction and the by-product of this reaction. [2]

Reagent	By-product
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(Option D continues on the following page)

(Option D, question 17 continued)

(b) The reaction can be monitored by infrared spectroscopy. Using section 26 of the data booklet, identify **two** IR absorbance ranges that would help distinguishing the two compounds. [2]

Present in morphine but not in diamorphine:

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Present in diamorphine but not in morphine:

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(c) Discuss how the differences in structure between morphine and diamorphine affect their absorption in the body. [3]

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(Option D continues on the following page)

(Option D continued)

18. Magnesium hydroxide is the active ingredient in a common antacid.

(a) Formulate the equation for the neutralization of stomach acid with magnesium hydroxide. [1]

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(b) Determine the mass of HCl, in g, that can be neutralized by the standard adult dose of 1.00 g magnesium hydroxide. [2]

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(c) Compare and contrast the use of omeprazole (Prilosec) and magnesium hydroxide. [3]

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(Option D continues on the following page)

(Option D continued)

19. Radioactive isotopes are used in a variety of medical procedures including medical imaging and radiotherapy.

(a) Identify examples of **two** types of medical radioactive waste and how **each** must be treated for proper disposal. [2]

Example	Treatment
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. . . . .	. . . . .

(b) Outline an ethical implication of using nuclear treatments in medicine. [1]

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End of Option D

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