AQA

Please write clearly in block capitals.

Centre number | | | | | | Candidate number | | | | |

Surname ______________________________

Forename(s) ______________________________

Candidate signature ______________________________

AS CHEMISTRY

Paper 2: Organic and Physical Chemistry

Friday 10 June 2016 Afternoon Time allowed: 1 hour 30 minutes

Materials
For this paper you must have:
- the Periodic Table/Data Sheet, provided as an insert (enclosed)
- a ruler with millimetre measurements
- a calculator, which you are expected to use where appropriate.

Instructions
- Use black ink or black ball-point pen.
- Answer **all** questions.
- You must answer the questions in the spaces provided. Do not write outside the box around each page or on blank pages.
- All working must be shown.
- Do all rough work in this book. Cross through any work you do not want to be marked.

Information
- The maximum mark for this paper is 80.
- The Periodic Table/Data Sheet is provided as an insert.

Advice
- You are advised to spend about 65 minutes on **Section A** and 25 minutes on **Section B**.

Section A

Answer **all** questions in this section.

1 Ethene reacts with steam in the presence of an acid catalyst to form ethanol.

$$CH_2{=}CH_2(g) + H_2O(g) \rightleftharpoons CH_3CH_2OH(g)$$

0 1 . 1 Write an expression for the equilibrium constant K_c for this equilibrium.
Deduce the units of K_c.

[2 marks]

Expression ______________________________

____

____

Units ______________________________

0 1 . 2 An equilibrium mixture was found to contain 0.700 mol of ethene, 1.20 mol of steam and 4.40 mol of ethanol at a temperature ***T***. The volume of the container was 2.00 dm^3.

Calculate a value of K_c for this equilibrium at this temperature.

Give your answer to an appropriate number of significant figures.

[2 marks]

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Turn over for the next question

DO NOT WRITE ON THIS PAGE
ANSWER IN THE SPACES PROVIDED

2 Alcohols such as methanol (CH_3OH), ethanol (CH_3CH_2OH) and propan-1-ol ($CH_3CH_2CH_2OH$) are good fuels.

0 2 . 1 A student carried out an experiment to determine the enthalpy of combustion of methanol.

Methanol was placed in a spirit burner and the mass of the spirit burner measured. The student placed 100 g of water in a copper calorimeter and clamped it above the spirit burner. The burner was lit and allowed to burn for a few minutes. The flame was then extinguished and the new mass of the spirit burner found.

The measured temperature rise was 38.0 °C. The specific heat capacity of water is 4.18 J K^{-1} g^{-1}.

Figure 1, a diagram of the apparatus, is shown alongside **Table 1** which shows the measurements the student recorded.

Figure 1

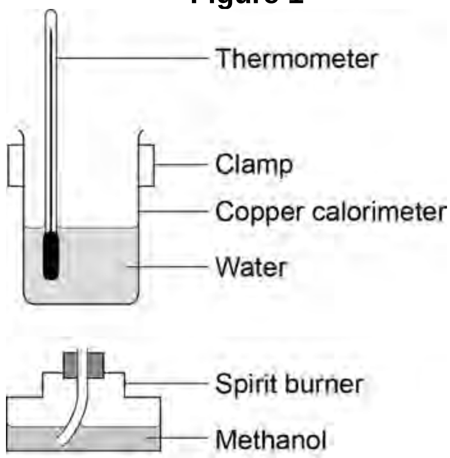

Table 1

Mass of burner containing methanol before experiment	214.02 g
Mass of burner containing methanol after experiment	212.37 g

Use the student's data to calculate an experimental value for the enthalpy of combustion of methanol in kJ mol^{-1}.

[4 marks]

0 2 . 2 Suggest **one** reason, other than incomplete combustion or heat transfer to the atmosphere, why the student's value for the enthalpy of combustion of methanol is different from that in a Data Book.

[1 mark]

____

____

0 2 . 3 The uncertainty in each of the temperature readings from the thermometer in this experiment was ±0.25 °C. This gave an overall uncertainty in the temperature rise of ±0.5 °C.

Calculate the percentage uncertainty for the use of the thermometer in this experiment.

[1 mark]

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0 2 . 4 The student said correctly that using a thermometer with an overall uncertainty for the rise in temperature of ±0.5 °C was adequate for this experiment.

Explain why this thermometer was adequate for this experiment.

[1 mark]

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0 2 . 5 The enthalpy of combustion of ethanol is −1371 kJ mol^{-1}. The density of ethanol is 0.789 g cm^{-3}.

Calculate the heat energy released in kJ when 0.500 dm^3 of ethanol is burned. Give your answer to an appropriate number of significant figures.

[3 marks]

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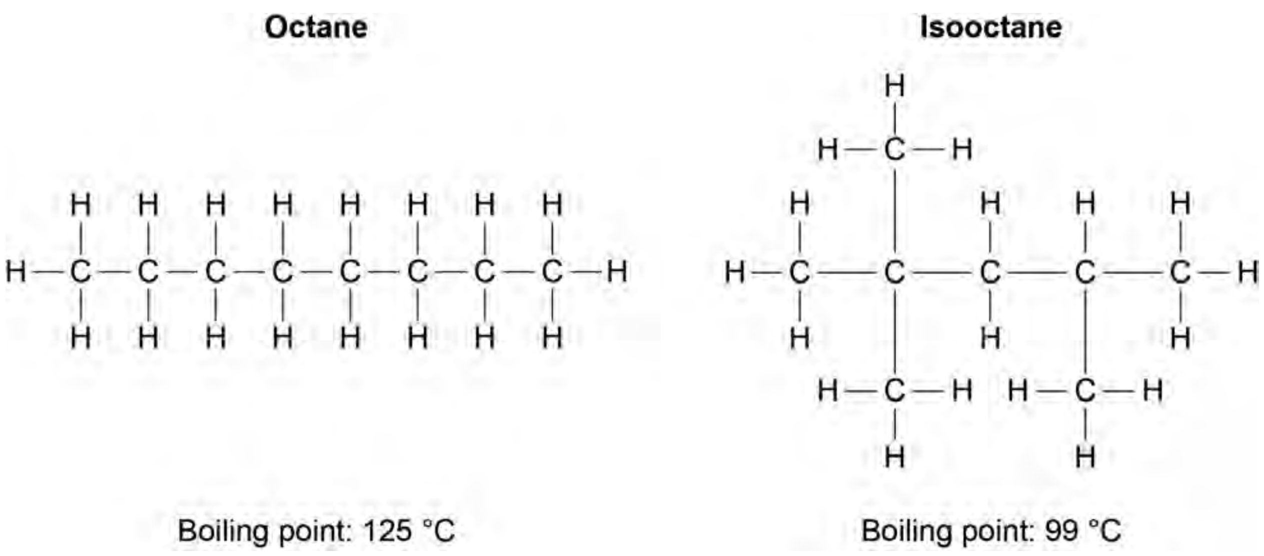
3 Octane and isooctane are structural isomers with the molecular formula C_8H_{18}
The displayed formulas and boiling points of octane and isooctane are shown in **Figure 2**.

Figure 2



0 3 . 1 Give the IUPAC name for isooctane.

[1 mark]

0 3 . 2 Octane and isooctane can be separated in the laboratory.

Name a laboratory technique that could be used to separate isooctane from a mixture of octane and isooctane.

Outline how this technique separates isooctane from octane.

[3 marks]

Name

Outline

0 3 . 3 Isooctane is added to petrol to increase its octane rating. Some high-performance engines require fuel with a higher octane rating.

Write an equation for the complete combustion of isooctane. Use the molecular formula (C_8H_{18}) of isooctane in your equation.

[1 mark]

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0 3 . 4 Explain, in general terms, how a catalyst works.

[2 marks]

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0 3 . 5 Carbon monoxide is produced when incomplete combustion takes place in engines. Nitrogen monoxide is another pollutant produced in car engines.

Write an equation to show how these pollutants react together in a catalytic converter.

[1 mark]

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0 3 . 6 Platinum, palladium and rhodium are metals used inside catalytic converters. A very thin layer of the metals is used on a honeycomb ceramic support.

Explain why a thin layer is used in this way.

[2 marks]

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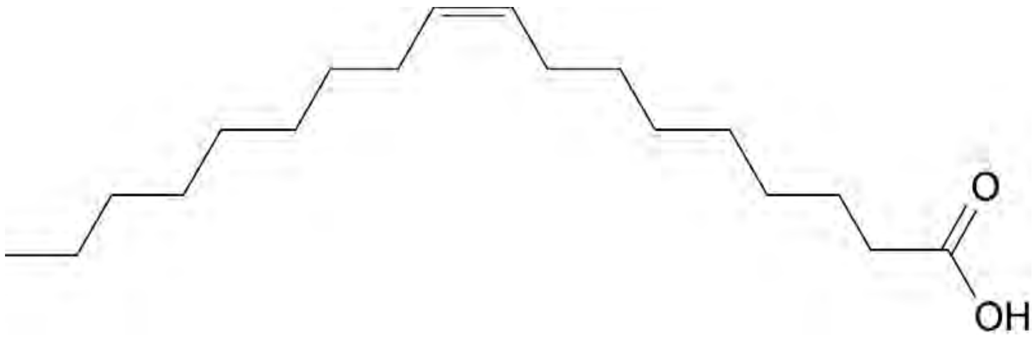
Question 3 continues on the next page

0 3 . 7 Oleic acid ($C_{18}H_{34}O_2$) is a straight-chain fatty acid obtained from plant oils. Isooctane can be made from oleic acid. The skeletal formula of oleic acid is shown in **Figure 3**.

Figure 3



Identify a reagent that could be used in a chemical test to show that oleic acid is unsaturated.

State what would be observed in this test.

[2 marks]

Reagent ______________________________

Observation ______________________________

____

Turn over for the next question

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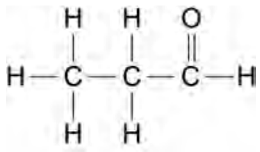
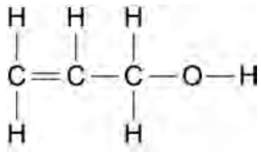
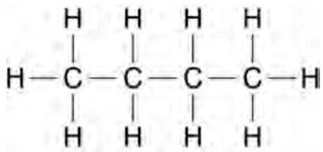
ANSWER IN THE SPACES PROVIDED

4 The compounds in **Table 2** all have a relative molecular mass of 58.0

Table 2

Name	Propanal	Prop-2-en-1-ol	Butane
Structure			

0 4 . 1 Explain why determining the precise relative molecular mass of propanal and prop-2-en-1-ol by mass spectrometry could not be used to distinguish between samples of these two compounds.

[2 marks]

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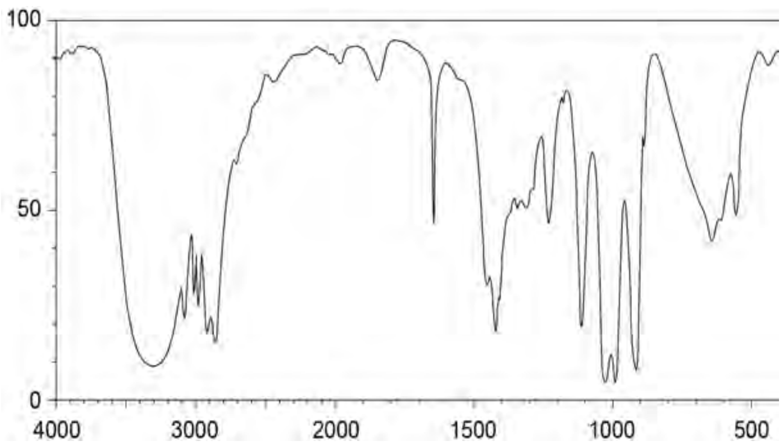
0 4 . 2 The infrared spectrum of one of these three compounds is shown in **Figure 4**.

Figure 4

Transmittance /%



Wavenumber /cm^{-1}

Use the spectrum to identify the compound.
State the bond that you used to identify the compound and give its wavenumber range. You should only consider absorptions with wavenumbers greater than 1500 cm^{-1}.

[2 marks]

Compound ______________________________

Bond used to identify compound ______________________________

Wavenumber range of bond used to identify compound ______________ cm^{-1}

0 4 . 3 Predict the relative boiling points of these three compounds from the highest to the lowest boiling points.

Justify this order in terms of intermolecular forces.

[6 marks]

5 Refrigerants are substances used to cool refrigerators and freezers. Until recently, many of the compounds used as refrigerants were chlorofluorocarbons (CFCs), but these are now known to form chlorine radicals. CFCs have been phased out in many countries by international agreement.

0 5 . 1 Write **two** equations to show how chlorine radicals react with ozone molecules in the upper atmosphere.

[2 marks]

1 ______________________________

2 ______________________________

0 5 . 2 Chloropentafluoroethane is a CFC that has been used as a refrigerant.

Draw its displayed formula.

[1 mark]

0 5 . 3 1,1,1-trifluoroethane (CF_3CH_3) is one of the molecules that has been used as a refrigerant in place of CFCs.

Explain why 1,1,1-trifluoroethane does not lead to the depletion of the ozone in the upper atmosphere.

[1 mark]

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0 5 . 4 One of the steps in the synthesis of 1,1,1-trifluoroethane (CF_3CH_3) is the reaction of 1,1-difluoroethane (CHF_2CH_3) with fluorine in a free-radical substitution reaction.

Write **two** equations to represent the propagation steps in this conversion of CHF_2CH_3 into CF_3CH_3

[2 marks]

Propagation step 1

___

Propagation step 2

___

0 5 . 5 A refrigerator contains 1.41 kg of 1,1,1-trifluoroethane (CF_3CH_3).

Calculate the number of molecules of 1,1,1-trifluoroethane in the refrigerator.
Give your answer to an appropriate number of significant figures.
(The Avogadro constant L = 6.022×10^{23} mol^{-1})

[2 marks]

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0 5 . 6 There are growing concerns about the use of 1,1,1-trifluoroethane as a refrigerant as it is a greenhouse gas that absorbs some of Earth's infrared radiation.

Give **one** reason why bonds in molecules such as carbon dioxide and 1,1,1-trifluoroethane absorb infrared radiation.

[1 mark]

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6 Propane-1,2-diol has the structure $CH_2(OH)CH(OH)CH_3$. It is used to make polyesters and is one of the main substances in electronic cigarettes (E-cigarettes).

A sample of propane-1,2-diol was refluxed with a large excess of potassium dichromate(VI) and sulfuric acid.

0 6 . 1 Draw the skeletal formula of propane-1,2-diol.

[1 mark]

0 6 . 2 Write an equation for this oxidation reaction of propane-1,2-diol under reflux, using [O] to represent the oxidizing agent.

Show the displayed formula of the organic product.

[2 marks]

0 6 . 3 Draw a labelled diagram to show how you would set up apparatus for refluxing.

[2 marks]

0 6 . 4 Anti-bumping granules are placed in the flask when refluxing.
Suggest why these granules prevent bumping.

[1 mark]

0 6 . 5 Draw the structure of a different organic product formed when the acidified potassium dichromate(VI) is not in excess.

[1 mark]

7 The alkene 3-methylpent-2-ene ($CH_3CH{=}C(CH_3)CH_2CH_3$) reacts with hydrogen bromide to form a mixture of 3-bromo-3-methylpentane and 2-bromo-3-methylpentane.

0 7 . 1 The alkene 3-methylpent-2-ene ($CH_3CH{=}C(CH_3)CH_2CH_3$) exists as *E* and *Z* stereoisomers.

Draw the structure of *Z*-3-methylpent-2-ene.

[1 mark]

0 7 . 2 Name and outline the mechanism for the formation of 3-bromo-3-methylpentane from this reaction of 3-methylpent-2-ene with hydrogen bromide.

Explain why more 3-bromo-3-methylpentane is formed in this reaction than 2-bromo-3-methylpentane.

[7 marks]

Turn over for the next question

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ANSWER IN THE SPACES PROVIDED

8 When an aqueous solution of ethanoic acid reacts with magnesium, the progress of reaction can be followed using the equipment shown in **Figure 5** to measure the volume of hydrogen produced.

Figure 5

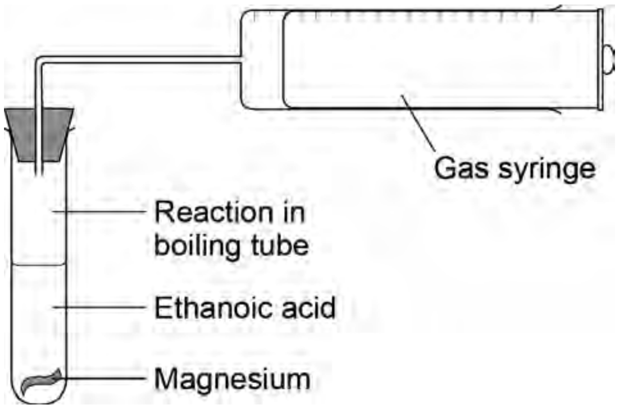
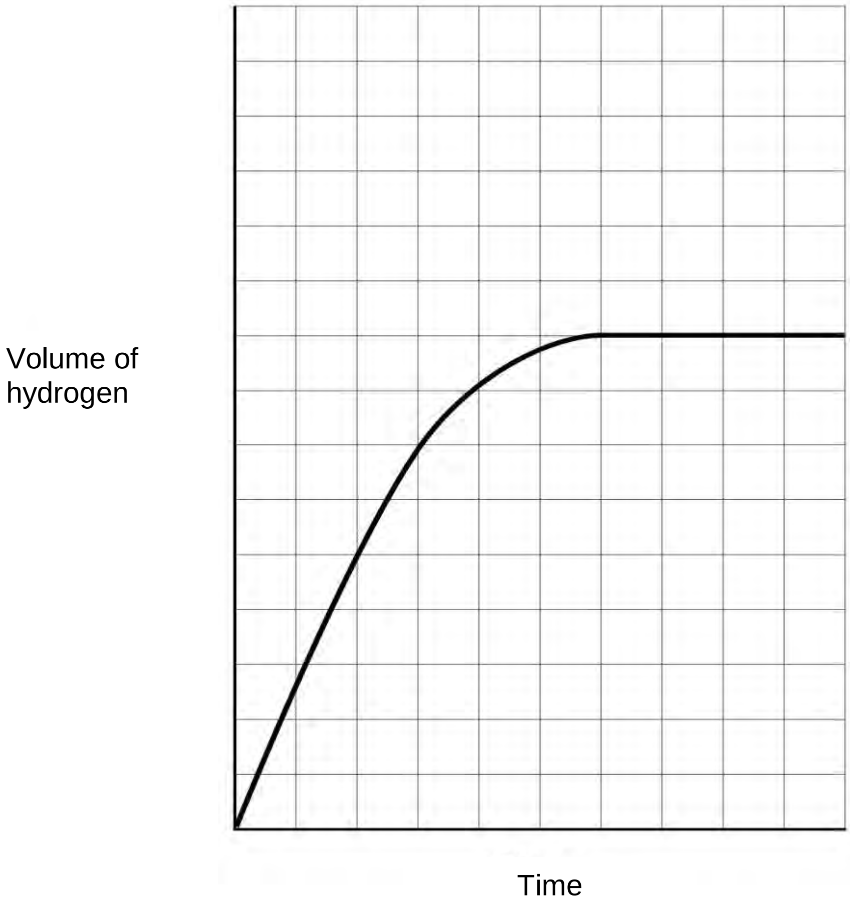


Figure 6 shows how the volume of hydrogen produced varies with time when 396 mg of magnesium are added to $30.0\ cm^3$ of $0.600\ mol\ dm^{-3}$ ethanoic acid.

Figure 6



0 8 . 1 The equation for the reaction between ethanoic acid and magnesium is shown.

$$2CH_3COOH(aq) + Mg(s) \rightarrow (CH_3COO)_2Mg(aq) + H_2(g)$$

With the aid of calculations, show that the magnesium is in excess in this reaction.

[3 marks]

0 8 . 2 The reaction was repeated using 20 cm^3 of 0.800 mol dm^{-3} of ethanoic acid solution with all other conditions the same. The magnesium was still in excess.

Sketch a line on **Figure 6** to show how the volume of hydrogen produced varies with time in this second experiment.

[2 marks]

Space for working.

Turn over for the next question

Section B

Answer **all** questions in this section.

Only **one** answer per question is allowed.
For each answer completely fill in the circle alongside the appropriate answer.

CORRECT METHOD WRONG METHODS

If you want to change your answer you must cross out your original answer as shown.

If you wish to return to an answer previously crossed out, ring the answer you now wish to select as shown.

You may do your working out in the blank spaces around the questions but this will not be marked. Do **not** use additional sheets for this working.

0 9 Which of the following compounds would form an orange-red precipitate when heated with Fehling's solution?

[1 mark]

A CH_3CH_2CN

B CH_3CH_2COOH

C CH_3CHO

D CH_3COCH_3

1 0 Pentanenitrile can be made by reaction of 1-bromobutane with potassium cyanide.

Which of these is the correct name for the mechanism of this reaction?

[1 mark]

A Electrophilic addition

B Electrophilic substitution

C Nucleophilic addition

D Nucleophilic substitution

1 1 Propene can be made by the dehydration of propan-2-ol.

What is the percentage yield when 30 g of propene (M_r = 42.0) are formed from 50 g of propan-2-ol (M_r = 60.0)?.

[1 mark]

A 60%

B 67%

C 81%

D 86%

1 2 Sulfur dioxide (SO_2) is produced when some fossil fuels are burned.

Which of the following statements is true?

[1 mark]

A Sulfur dioxide can be removed from waste gases in a power station by an acid-base reaction with calcium oxide.

B Sulfur dioxide is insoluble in water.

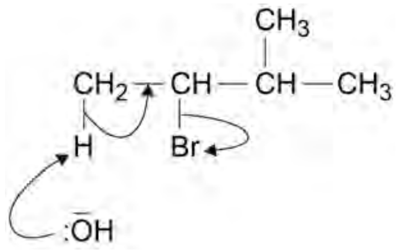
C Sulfur dioxide is a basic oxide.

D Sulfur dioxide is an ionic compound.

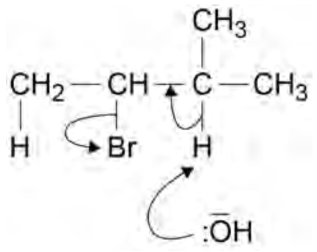
1 3 Which of the following is a correct mechanism for the formation of 2-methylbut-2-ene from 2-bromo-3-methylbutane?

[1 mark]

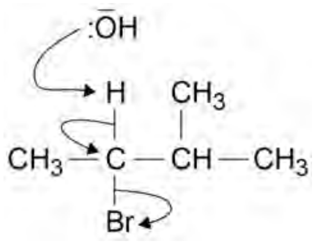
A



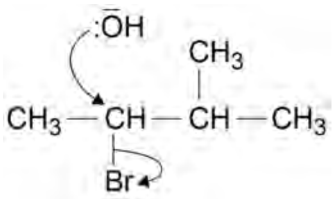
B



C



D



1 4 An organic compound is found to contain 40.0% carbon, 6.7% hydrogen and 53.3% oxygen.

Which of the following compounds could this be?

[1 mark]

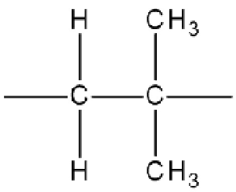
A Ethanol

B Ethanoic acid

C Methanol

D Methanoic acid

1 5 The repeating unit of a polymer is



Which of the following molecules would form a polymer containing this repeating unit?

[1 mark]

A But-1-ene

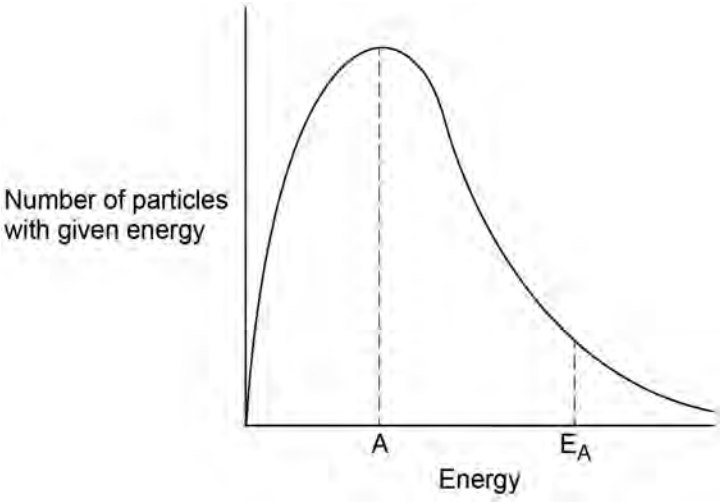
B *E*-but-2-ene

C *Z*-but-2-ene

D Methylpropene

1 6 **Figure 7** shows a typical energy distribution for particles of an ideal gas in a sealed container at a fixed temperature.

Figure 7



Which of the following statements is true?

[1 mark]

A Position A represents the mean energy of a molecule in the container. ⬭

B Addition of a catalyst moves the position of E_A to the right. ⬭

C The area under the curve to the right of E_A represents the number of molecules with enough energy to react. ⬭

D The position of the peak of the curve at a higher temperature is further away from both axes. ⬭

1 7 Tetradecane ($C_{14}H_{30}$) is an alkane found in crude oil. When tetradecane is heated to a high temperature, one molecule of tetradecane decomposes to form one molecule of hexane and three more molecules.

Which of the following could represent this reaction?

[1 mark]

A $C_{14}H_{30} \rightarrow C_6H_{14} + C_4H_8 + 2C_2H_4$ ⬭

B $C_{14}H_{30} \rightarrow C_6H_{14} + C_6H_{12} + C_2H_4$ ⬭

C $C_{14}H_{30} \rightarrow C_5H_{12} + 3C_3H_6$ ⬭

D $C_{14}H_{30} \rightarrow C_6H_{14} + C_2H_6 + 2C_3H_6$ ⬭

1 8 The structure of cyclohexene is shown.

Which of the following is the general formula of cyclic alkenes such as cyclohexene?

[1 mark]

A C_nH_{2n-4}

B C_nH_{2n-2}

C C_nH_{2n}

D C_nH_{2n+2}

1 9 **A** and **B** react together in this reversible reaction.

$$\mathbf{A + 3B \rightleftharpoons C + 2D}$$

A mixture of 10 mol of **A** and 10 mol of **B** were left to reach equilibrium. The equilibrium mixture contained 4 mol of **B**.

What is the total amount, in moles, of substances in the equilibrium mixture?

[1 mark]

A 14

B 16

C 18

D 20

2 0 The M_r of hydrated copper sulfate ($CuSO_4.5H_2O$) is 249.6.

Which of the following is the mass of hydrated copper sulfate required to make 50.0 cm^3 of a 0.400 mol dm^{-3} solution?

[1 mark]

A 3.19 g

B 3.55 g

C 3.71 g

D 4.99 g

Questions **21** and **22** refer to the production of hydrogen by the reaction of methane with steam. The reaction mixture reaches a state of dynamic equilibrium.

$$CH_4(g) + H_2O(g) \rightleftharpoons CO(g) + 3H_2(g) \quad \Delta H = +206 \text{ kJ mol}^{-1}$$

2 1 Which of the following shows how the equilibrium yield of hydrogen and the value of the equilibrium constant are affected by the changes shown?

[1 mark]

	Change	**Effect on equilibrium yield of $H_2(g)$**	**Effect on value of K_c**	
A	Increase pressure	decrease	decrease	⬭
B	Add a catalyst	increase	no effect	⬭
C	Increase temperature	increase	increase	⬭
D	Remove CO(g) as formed	increase	increase	⬭

2 2 Some enthalpy data is given in **Table 3**.

Table 3

Bond	C−H	O−H	H−H	C≡O
Bond enthalpy / kJ mol^{-1}	413	463	436	To be calculated

Use the information in **Table 3** and the stated enthalpy change to calculate the missing bond enthalpy.

[1 mark]

A 234 ⬭

B 1064 ⬭

C 1476 ⬭

D 1936 ⬭

Turn over for the next question

2 3 2 mol of ideal gas **X** are stored in a flask of fixed volume.

Which of the following changes would lead to the greatest increase in pressure inside the flask?

[1 mark]

A Increasing the temperature from 20 °C to 200 °C

B Adding another 1 mol of gas **X** into the flask at fixed temperature

C Adding 0.5 mol of argon gas and increasing the temperature from 20 °C to 150 °C

D Removing 0.5 mol of gas **X** and increasing the temperature from 20 °C to 300 °C

END OF QUESTIONS