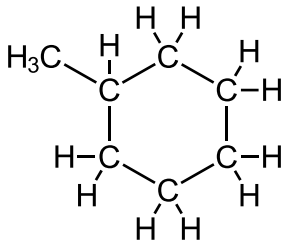
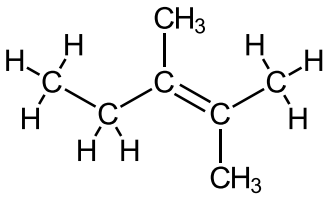
“READY FOR A LEVEL” – ORGANIC & PHYSICAL CHEMISTRY

1 This question is about the following hydrocarbons.



A



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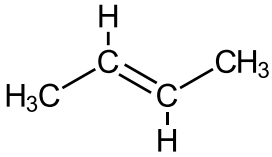

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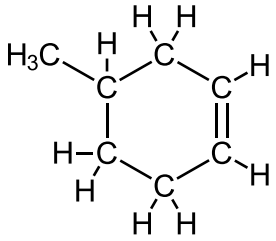

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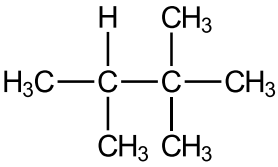
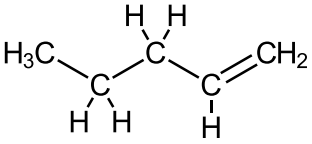


E



F

(a) What is the molecular formula of compound **F**?

..... **[1]**

(b) Which compounds are saturated hydrocarbons?

..... **[1]**

(c) Which compounds are members of the same homologous series?

..... **[1]**

(d) Which compounds have the same general formula?

..... **[1]**

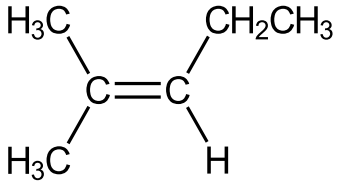
(e) Which compound could have been formed from the cracking of a nonane (C_9H_{20}) molecule?

..... **[1]**

(f) What is the name of compound **C**?

..... **[1]**

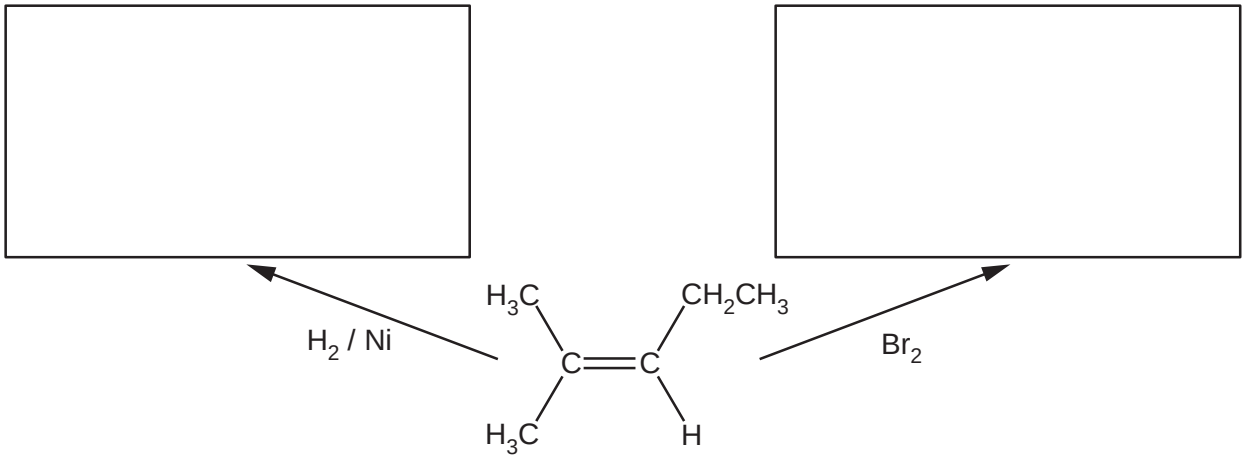
2 Compound **G** is an alkene that can be used as the starting material for making organic compounds.



compound G

(a) The flowchart shows three reactions of compound **G**.

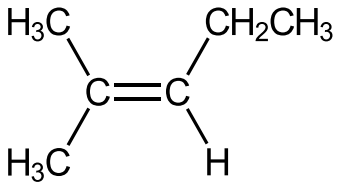
Complete the flowchart to show the organic products formed by the reactions.



compound G

[2]

(b) Compound **G** can be polymerised.



compound G

(i) Name the type of polymerisation.

..... **[1]**

(ii) Write a balanced equation for the polymerisation of **G**.

The equation should include the structure of the repeat unit of the polymer.

[2]

(c) A student plans to prepare 1-bromohexane, $CH_3(CH_2)_5Br$ by reacting hexane with bromine. The equation and two relative molecular masses are shown below.

$$CH_3(CH_2)_4CH_3 + Br_2 \longrightarrow CH_3(CH_2)_5Br + HBr$$

M_r ($CH_3(CH_2)_4CH_3$) = 86.0 M_r ($CH_3(CH_2)_5Br$) = 164.9

(i) Calculate the atom economy of this reaction.

Give your answer to **one** decimal place.

atom economy = ……..% **[1]**

(ii) When the student carries out this preparation, the student reacts 12.90 g of hexane but only 2.31 g of 1-bromohexane are obtained.

Calculate the percentage yield of 1-bromohexane from this preparation.

Give your answer to **three** significant figures.

percentage yield of 1-bromohexane = ...% **[3]**

3 Ammonia, NH_3, is manufactured by the chemical industry in the Haber process.

Nitrogen and hydrogen gases are reacted together in the presence of an iron catalyst.
The equation for this reversible reaction is shown below.

$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g) \qquad \Delta H = -92\,kJ\,mol^{-1}$$

(a) Suggest sources for the N_2 and H_2 used by the chemical industry.

N_2: .....

H_2: .....

[2]

(b) Predict the conditions of pressure and temperature that would give the maximum equilibrium yield of NH_3.

Explain your reasoning.

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..... **[4]**

(c) Explain why the actual temperature and pressure used by the chemical industry may be different from those required for a maximum equilibrium yield.

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..... **[2]**

(d) State **two** ways that the use of an iron catalyst helps the chemical industry to manufacture ammonia more sustainably and with less harm to the environment.

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.....

.....

..... **[2]**

(e) The combustion of ammonia produces nitrogen gas and steam, as shown below.

$$4NH_3(g) + 3O_2(g) \longrightarrow 2N_2(g) + 6H_2O(g)$$

The enthalpy change of this reaction can be calculated using the average bond enthalpies below.

Bond	Average bond enthalpy / kJ mol^{-1}
N–H	+391
O–H	+464
O=O	+498
N≡N	+945

(i) What is meant by the term *average bond enthalpy*?

.....

.....

..... **[2]**

(ii) Calculate the enthalpy change of this reaction, ΔH_r.

$$4NH_3(g) + 3O_2(g) \longrightarrow 2N_2(g) + 6H_2O(g)$$

ΔH_r = ... kJ mol^{-1} **[3]**

4 This question is about different alcohols.

(a) Ethanol is the most widely used alcohol.

Two main methods are used for the industrial production of ethanol.

For each method, state the reagents and essential conditions, and write an equation.

method 1: .....

.....

.....

method 2: .....

.....

.....

[6]

(b) Alcohols can be converted into organic compounds containing different functional groups.

Describe a reaction that would convert ethanol into a carboxylic acid

Include reagents, conditions and an equation for the reaction.

Show structures of the organic product, with functional groups fully displayed.

Your answer needs to be clear and well organised using the correct terminology, and linking the reactions to the functional groups.

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..... **[4]**

TOTAL = 40 marks

ANSWERS

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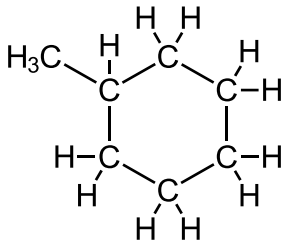

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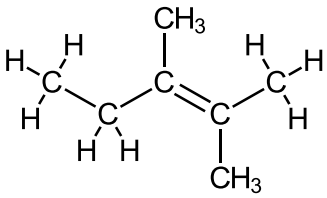

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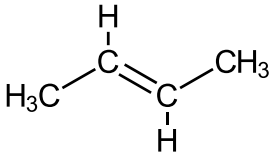

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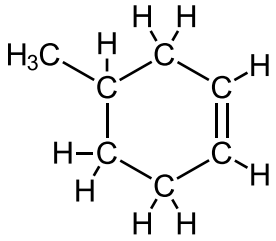

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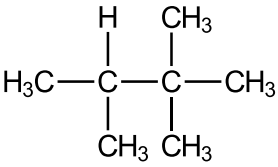

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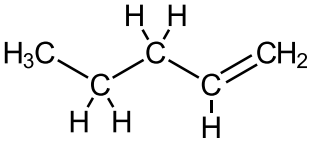


F

(a) What is the molecular formula of compound **F**?

C_5H_{10} ✓ **[1]**

(b) Which compounds are saturated hydrocarbons?

A **and** E ✓ **[1]**

(c) Which compounds are members of the same homologous series?

B, C, D **and** F ✓ **[1]**

(d) Which compounds have the same general formula?

A, B, C **and** F ✓ **[1]**

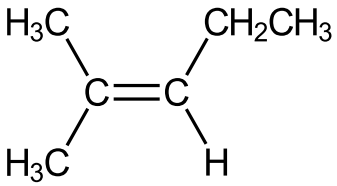
(e) Which compound could have been formed from the cracking of a nonane (C_9H_{20}) molecule?

F ✓ **[1]**

(f) What is the name of compound **C**?

butene ✓ (properly, but-2-ene) **[1]**

2 Compound **G** is an alkene that can be used as the starting material for making organic compounds.



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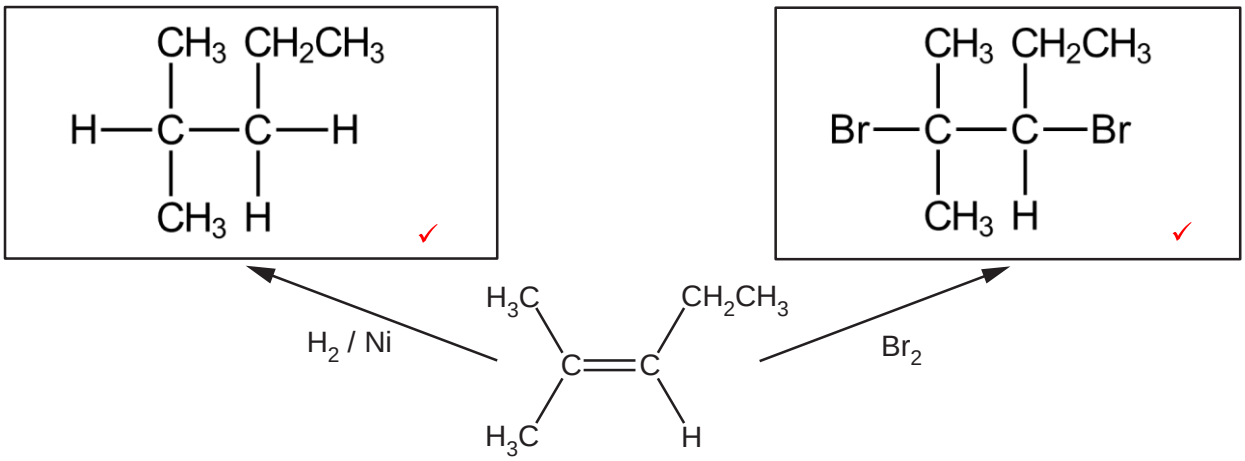
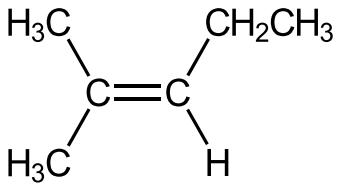


compound G

[2]

(b) Compound **G** can be polymerised.



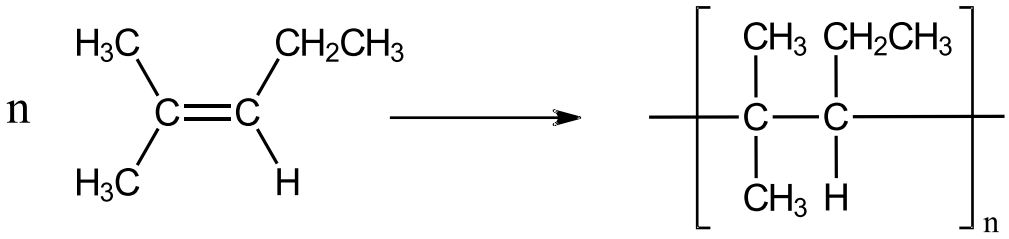
compound G

(i) Name the type of polymerisation.

Addition ✓ **[1]**

(ii) Write a balanced equation for the polymerisation of **G**.

The equation should include the structure of the repeat unit of the polymer.



Repeat unit of polymer with brackets ✓

"n" to balance before monomer and after brackets ✓

[2]

(c) A student plans to prepare 1-bromohexane, $CH_3(CH_2)_5Br$ by reacting hexane with bromine. The equation and two relative molecular masses are shown below.

$$CH_3(CH_2)_4CH_3 + Br_2 \longrightarrow CH_3(CH_2)_5Br + HBr$$

M_r $(CH_3(CH_2)_4CH_3)$ = 86.0 M_r $(CH_3(CH_2)_5Br)$ = 164.9

(i) Calculate the atom economy of this reaction.

Give your answer to **one** decimal place.

Atom economy = [164.9 / (164.9 + 81)] x 100

= 67.1 % ✓

atom economy = 67.1 (✓) % **[1]**

(ii) When the student carries out this preparation, the student reacts 12.90 g of hexane but only 2.31 g of 1-bromohexane are obtained.

Calculate the percentage yield of 1-bromohexane from this preparation.

Give your answer to **three** significant figures.

Number of moles of hexane reacted = 12.90 / 86 = 0.15 moles ✓

Number of moles of bromohexane = 0.15 moles (1:1 ratio in equation), so…

Mass of bromohexane expected = 0.15 x 164.9 = 24.735 g ✓

% yield = (2.31 / 24735) x 100 = 9.34 % ✓

percentage yield of 1-bromohexane = 9.34 (✓✓✓) % **[3]**

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Nitrogen and hydrogen gases are reacted together in the presence of an iron catalyst.
The equation for this reversible reaction is shown below.

$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g) \qquad \Delta H = -92\,kJ\,mol^{-1}$$

(a) Suggest sources for the N_2 and H_2 used by the chemical industry.

N_2: air ✓

H_2: methane / natural gas **or** water ✓

[2]

(b) Predict the conditions of pressure and temperature that would give the maximum equilibrium yield of NH_3.

Explain your reasoning.

Temperature = low ✓

Because forward reaction is exothermic ✓

Pressure = high ✓

Because there are fewer gas molecules on the right side of the equation ✓

[4]

(c) Explain why the actual temperature and pressure used by the chemical industry may be different from those required for a maximum equilibrium yield.

Actual temperature is higher **and**

Because low temperature gives a slow rate of reaction ✓

Actual pressure is lower **and**

Because high pressure is expensive to maintain / dangerous ✓ **[2]**

(d) State **two** ways that the use of an iron catalyst helps the chemical industry to manufacture ammonia more sustainably and with less harm to the environment.

Any **two** from

Requires less energy (✓)

Uses less fuel (✓)

Produces less waste (✓)

[2]

(e) The combustion of ammonia produces nitrogen gas and steam, as shown below.

$$4NH_3(g) + 3O_2(g) \longrightarrow 2N_2(g) + 6H_2O(g)$$

The enthalpy change of this reaction can be calculated using the average bond enthalpies below.

Bond	Average bond enthalpy / kJ mol^{-1}
N–H	+391
O–H	+464
O=O	+498
N≡N	+945

(i) What is meant by the term *average bond enthalpy*?

The amount of energy required to break ✓

One mole of covalent bonds ✓

[2]

(ii) Calculate the enthalpy change of this reaction, ΔH_r.

$$4NH_3(g) + 3O_2(g) \longrightarrow 2N_2(g) + 6H_2O(g)$$

Bonds broken = (12 x 391) + (3 x 498) = 6186 ✓

Bonds formed = (2 x 945) + (12 x 464) = 7458 ✓

Energy change = 6186 – 7458 = **-** 1272 ✓

IF answer = 1272 (no sign) or +1272 allow 2 marks

ΔH_r = **-** 1272 (✓✓✓) kJ mol^{-1} **[3]**

4 This question is about different alcohols.

(a) Ethanol is the most widely used alcohol.

Two main methods are used for the industrial production of ethanol.

For each method, state the reagents and essential conditions, and write an equation.

method 1: fermentation ✓

Yeast **and** 37°C (allow 36 or 38) ✓

$C_6H_{12}O_6 \rightarrow 2C_2H_6O + 2CO_2$ ✓

method 2: hydration of ethane ✓

steam **and** acid catalyst (H_3PO_4) ✓ *do not allow "water"*

$C_2H_4 + H_2O \rightarrow C_2H_6O$ ✓

[6]

(b) Alcohols can be converted into organic compounds containing different functional groups.

Describe a reaction that would convert ethanol into a carboxylic acid

Include reagents, conditions and an equation for the reaction.

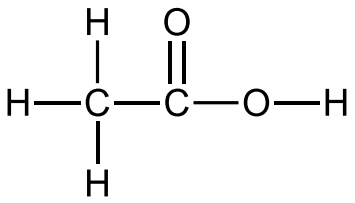
Show structures of the organic product, with functional groups fully displayed.

Your answer needs to be clear and well organised using the correct terminology, and linking the reactions to the functional groups.

Oxidation ✓

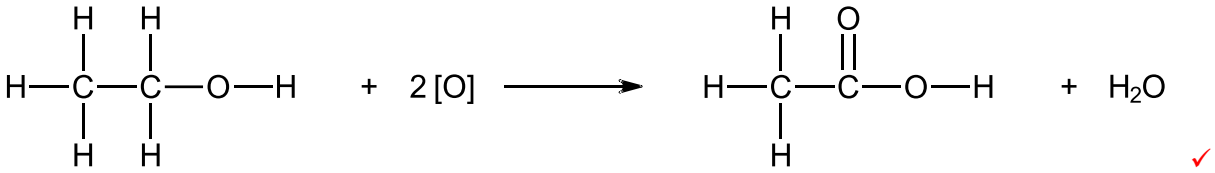
Reagents: acidified potassium dichromate ✓ *allow $K_2Cr_2O_7$*

Product:



✓ *allow from equation*

Equation:



✓

[4]

TOTAL = 40 marks