RADLEY

2021 Academic Scholarship Examination Paper

STAGE TWO

CHEMISTRY

23 – 25 February 2021

Time allowed: 30 minutes

Total marks: 28

Candidate's name: _____

PLEASE WRITE IN BLACK INK

Calculators are not allowed.

Please write on the paper provided.

You are unlikely to have come across most of the questions below. Don't worry, everything you need is given to you. Read the information given in the questions carefully and use it to reason your answers.

1. Fossil fuels have arguably been the single most important energy source in the world and still enjoy this status today. Crude oil is one type of fossil fuel which is a mixture of many hydrocarbons.

Examples of the simplest hydrocarbons are shown in Table 1 below. The displayed formula shows you how the carbon and hydrogen atoms are connected (with the straight lines '-'). The condensed formula is just what it says. A kind of displayed formula but without the lines.

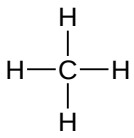
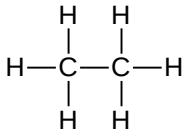
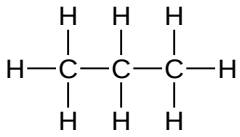
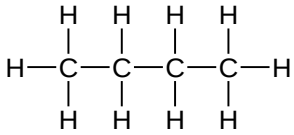
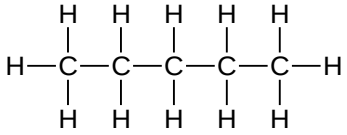
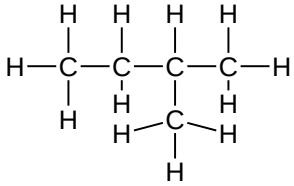
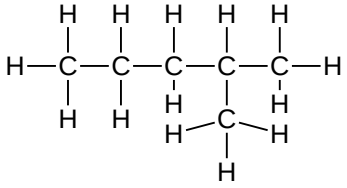
Name of hydrocarbon	**Displayed formula**	**Condensed formula**	**Molecular formula**	**Empirical formula**
methane		CH_4	CH_4	CH_4
ethane		CH_3CH_3	C_2H_6	CH_3
propane		$CH_3CH_2CH_3$	C_3H_8	C_3H_8
butane		$CH_3CH_2CH_2CH_3$	C_4H_{10}	C_2H_5
pentane		$CH_3CH_2CH_2CH_2CH_3$	C_5H_{12}	C_5H_{12}
2-methylbutane		$CH_3CH_2CHCH_3CH_3$	***see Question 2 below***	***see Question 5 below***
see Question 8 below		***see Question 8 below***	C_6H_{14}	C_3H_7

Table 1

1. Given that ethanol, CH_3CH_2OH, is not a hydrocarbon, suggest a definition for the term *hydrocarbon*.

[1]

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2. Predict the molecular formula for 2-methylbutane from the table above.

[1]

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3. Suggest the empirical formulae for the following two compounds:

[2]

a) $C_6H_{12}O_6$ b) C_9H_{20}

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4. What do you think the molecular formula tells you?

[2]

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5. Give the empirical formal of 2-methylbutane

[1]

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6. What do you think the empirical formula tells you?

[1]

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7. Pentane and 2-methyl butane are called isomers as they have the same molecular formula but a different structure. Can you draw another isomer that belongs to pentane?

[1]

8. This question refers to the last row in Table 1 above.

a) Give the name of the hydrocarbon.

[1]

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b) Give the condensed formula.

[1]

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9. As you can see from Table 1 above each carbon has four bonds to four other atoms (here hydrogens). The bonds are signified by a line '-'

Draw the displayed formula of two **different** hydrocarbons that both have a total of seven carbon atoms.

[2]

10. Write the molecular formula of the hydrocarbon that has ten carbon atoms.

[1]

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11. Look closely at Table 1. Can you find a general molecular formular for the hydrocarbons? That means for a given number of carbon atoms, n, how many hydrogen atoms must be present? Express your answer in terms of *n*.

[1]

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12. Petrol is a mixture of various hydrocarbons with 4 to 12 carbon atoms. It is obtained by distillation of crude oil. Answer the questions below.

a) On what physical property is distillation based? When is distillation used in a separation process?

[2]

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b) Table 2 below shows the parts of crude oil (called fractions) obtained from the distillation process.

Fraction	**Boiling point / ^{o}C**	**Number of carbon atoms in the hydrocarbons.**
Refinery gas	-16 – -5	1 – 4
Petrol	40 – 110	5 – 8
Naphtha	110 – 180	8 – 10
Kerosene	180 – 260	10 – 16
Diesel	260 – 320	16 – 20
Fuel Oil	320 – 400	20 – 50
Bitumen	400 – 600	> 50

Table 2

(i) Suggest a relationship between chain length and boiling point.

[1]

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(ii) Pentadecane is a hydrocarbon with a boiling point of 271 °C. In which fraction would you find pentadecane?

[1]

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(iii) Table 3 summarises the yearly demand for some of the fractions of crude oil.

Fraction	Uses	Summer demand	Winter demand
Refinery gas	Gaseous fuel (bottled gas), chemical production	4%	3%
Gasoline (petrol)	Automobile fuel, chemical production	32%	29%
Kerosene (paraffin)	Heating fuel, jet fuel	12%	6%
Diesel oil	Diesel fuel for trucks, buses, trains, etc.; heating fuel	17%	23%
Residue fuel	Fuel for power stations, ships, etc.; can be distilled further into lubricating oil, waxes, etc.	35%	39%

Table 3

Suggest why in the winter the demand for Gasoline is lower and Diesel oil higher.

[2]

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13. Kerosene is one of the fractions obtained from crude oil. It is a liquid with density of 0.800 g cm^{-3} and is also used to store reactive metals such as sodium and potassium. It prevents oxygen from reacting with the metals. Using Table 4 suggest why the reactive metal lithium can still react with oxygen when it is stored in kerosene?

Metal	**Density / g cm^{-3}**
Lithium	0.534
Sodium	0.968
Potassium	0.89
Rubidium	1.532

Table 4

[2]

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14. One kilogram of petrol has an energy content of 45 000 000 J. This is 45 megajoules per kilogram or 45 ⅃ 10^6 J kg^{-1}. A typical car can hold about 50 litres of petrol.

a) Calculate in Joules (J), the energy that would be released when the 50 litres of petrol are combusted in a petrol engine. (The density of petrol is 0.775 kg/litre.)

[3]

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b) Give your answer above in megajoules (MJ) and to four significant figures.

[2]

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