Topic 10/20 Practice written questions organic chemistry *[73 marks]*

This question is about carbon and chlorine compounds.

1a. Ethane, C_2H_6, reacts with chlorine in sunlight. State the type of this reaction and the name of the mechanism by which it occurs. *[1 mark]*

Type of reaction:

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Mechanism:

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1b. Formulate equations for the two propagation steps and one termination step in the formation of chloroethane from ethane. *[3 marks]*

Two propagation steps:

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One termination step:

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1c. One possible product, **X**, of the reaction of ethane with chlorine has the following composition by mass: *[2 marks]*

carbon: 24.27%, hydrogen: 4.08%, chlorine: 71.65%

Determine the empirical formula of the product.

1d. Chloroethene, C_2H_3Cl, can undergo polymerization. Draw a section of the polymer with three repeating units. *[1 mark]*

Benzene is an aromatic hydrocarbon.

2a. Discuss the physical evidence for the structure of benzene. *[2 marks]*

2b. State the typical reactions that benzene and cyclohexene undergo with bromine.   *[1 mark]*

Benzene:

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Cyclohexene:

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The photochemical chlorination of methane can occur at low temperature.

3a. Using relevant equations, show the initiation and the propagation steps for this reaction.   *[3 marks]*

Initiation:

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Propagation:

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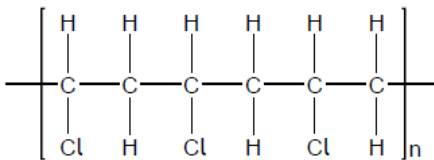
3b. Bromine was added to hexane, hex-1-ene and benzene. Identify the compound(s) which will react with bromine in a well-lit laboratory.   *[1 mark]*

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3c. Polyvinyl chloride (PVC) is a polymer with the following structure. [1 mark]

State the structural formula for the monomer of PVC.

This question is about carbon and chlorine compounds.

4a. Ethane, C_2H_6, reacts with chlorine in sunlight. State the type of this reaction and the name of the mechanism by which it occurs. [1 mark]

Type of reaction:

Mechanism:

4b. Formulate equations for the two propagation steps and one termination step in the formation of chloroethane from ethane. *[3 marks]*

Two propagation steps:

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One termination step:

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4c. Deduce the splitting patterns in the ^{1}H NMR spectrum of C_2H_5Cl. *[1 mark]*

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4d. Explain why tetramethylsilane (TMS) is often used as a reference standard in ^{1}H NMR. *[2 marks]*

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4e. One possible product, **X**, of the reaction of ethane with chlorine has the following composition by mass: [2 marks]
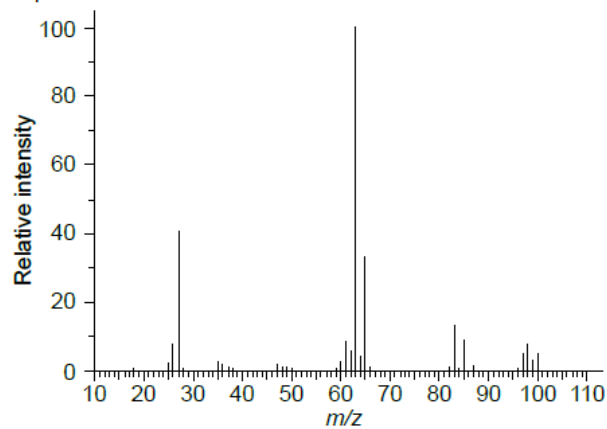
carbon: 24.27%, hydrogen: 4.08%, chlorine: 71.65%

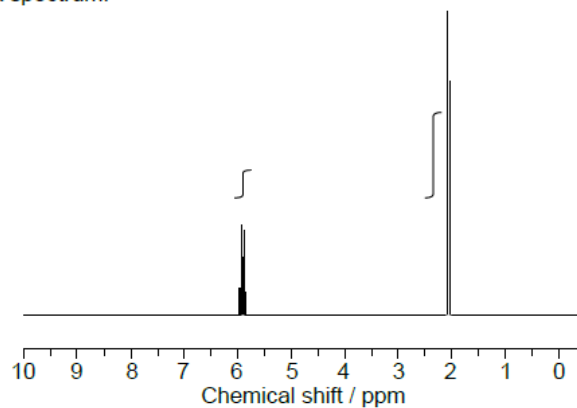Determine the empirical formula of the product.

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4f. The mass and ^1H NMR spectra of product **X** are shown below. Deduce, giving your reasons, its structural formula and hence the [3 marks] name of the compound.

Mass spectrum:

Relative intensity

100

80

60

40

20

0

10   20   30   40   50   60   70   80   90   100   110
m/z

^1H NMR spectrum:

10   9   8   7   6   5   4   3   2   1   0
Chemical shift / ppm

[Source: http://sdbs.db.aist.go.jp]

4g. When the product **X** is reacted with NaOH in a hot alcoholic solution, C_2H_3Cl is formed. State the role of the reactant NaOH other [1 mark] than as a nucleophile.

4h. Chloroethene, C_2H_3Cl, can undergo polymerization. Draw a section of the polymer with three repeating units. *[1 mark]*

An acidic sample of a waste solution containing Sn^{2+}(aq) reacted completely with $K_2Cr_2O_7$ solution to form Sn^{4+}(aq).

5a. Identify one organic functional group that can react with acidified $K_2Cr_2O_7$(aq). *[1 mark]*

5b. Corrosion of iron is similar to the processes that occur in a voltaic cell. The initial steps involve the following half-equations: *[1 mark]*

$$Fe^{2+}(aq) + 2e^- \rightleftharpoons Fe(s)$$

$$\tfrac{1}{2}O_2(g) + H_2O(l) + 2e^- \rightleftharpoons 2OH^-(aq)$$
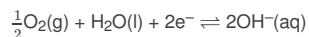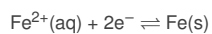
Calculate E^θ, in V, for the spontaneous reaction using section 24 of the data booklet.

5c. Calculate the Gibbs free energy, ΔG^θ, in kJ, which is released by the corrosion of 1 mole of iron. Use section 1 of the data booklet. *[2 marks]*

5d. Explain why iron forms many different coloured complex ions. [3 marks]

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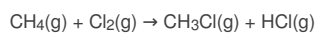
5e. Zinc is used to galvanize iron pipes, forming a protective coating. Outline how this process prevents corrosion of the iron pipes. [1 mark]

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6. The overall equation for monochlorination of methane is: [2 marks]

$$CH_4(g) + Cl_2(g) \rightarrow CH_3Cl(g) + HCl(g)$$

Calculate the standard enthalpy change for the reaction, ΔH^θ, using section 12 of the data booklet.

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7a. Bromine was added to hexane, hex-1-ene and benzene. Identify the compound(s) which will react with bromine in a well-lit laboratory. [1 mark]

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7b. Deduce the structural formula of the main organic product when hex-1-ene reacts with hydrogen bromide.   *[1 mark]*

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7c. State the reagents and the name of the mechanism for the nitration of benzene.   *[2 marks]*

Reagents:

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Name of mechanism:

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7d. Outline, in terms of the bonding present, why the reaction conditions of halogenation are different for alkanes and benzene.   *[1 mark]*
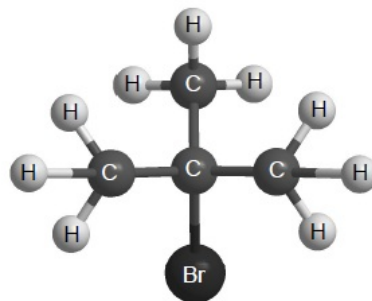
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Below are two isomers, A and B, with the molecular formula C_4H_9Br.
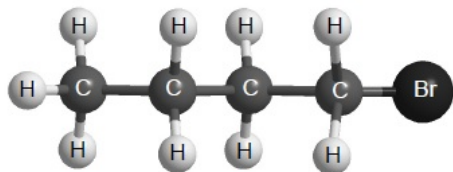
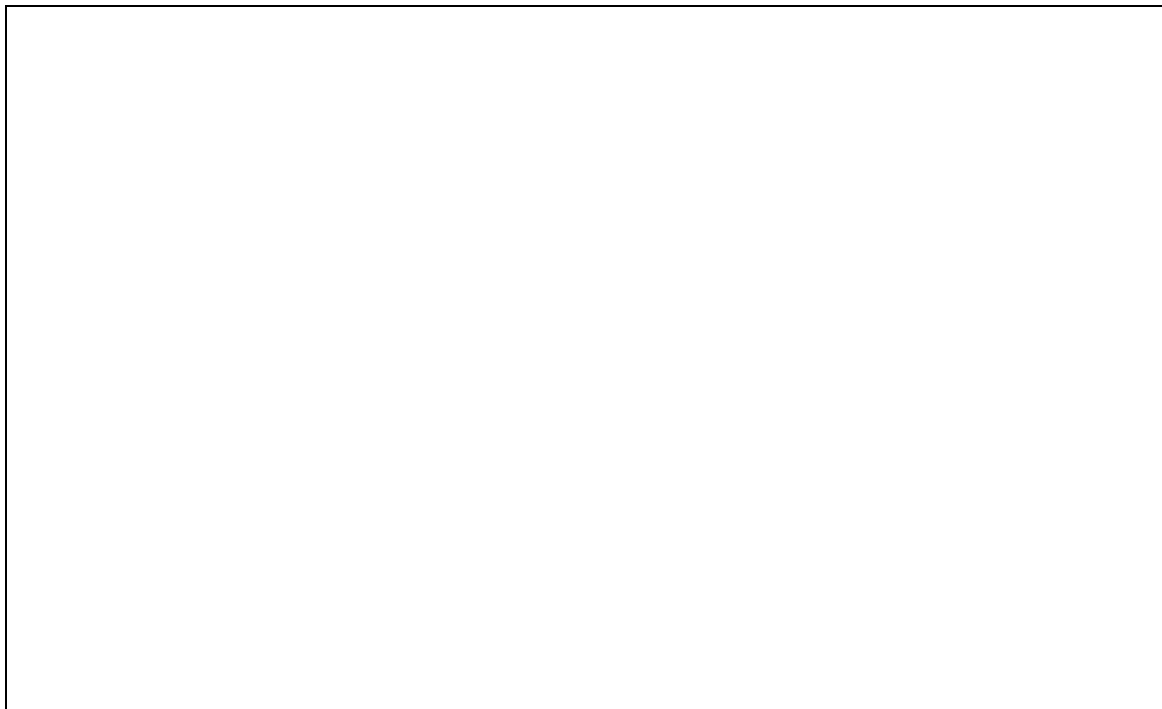
A   B

Explain the mechanism of the nucleophilic substitution reaction with NaOH(aq) for the isomer that reacts almost exclusively by an S_N2 mechanism using curly arrows to represent the movement of electron pairs.

The Bombardier beetle sprays a mixture of hydroquinone and hydrogen peroxide to fight off predators. The reaction equation to produce the spray can be written as:

$C_6H_4(OH)_2(aq) + H_2O_2(aq) \rightarrow C_6H_4O_2(aq) + 2H_2O(l)$
hydroquinone   quinone
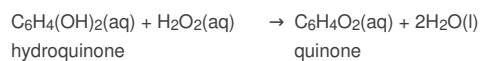
8a. Hydrogenation of propene produces propane. Calculate the standard entropy change, $\Delta S^\ominus$, for the hydrogenation of propene.   *[2 marks]*

Formula	$S^\ominus$ / $JK^{-1}mol^{-1}$
$H_2(g)$	+131
$C_3H_6(g)$	+267
$C_3H_8(g)$	+270

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8b. The standard enthalpy change, $\Delta H^\ominus$, for the hydrogenation of propene is −124.4 kJ mol^{-1}. Predict the temperature above which   *[2 marks]*
the hydrogenation reaction is not spontaneous.

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Infrared (IR) spectroscopy is often used for the identification of polymers, such as PETE, for recycling.

LDPE and high density polyethene (HDPE) have very similar IR spectra even though they have rather different structures and physical properties.

9. Explain why the difference in their structures affects their melting points. *[2 marks]*

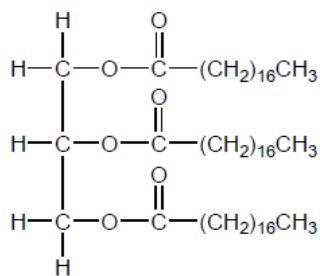Vegetable oils, such as that shown, require conversion to biodiesel for use in current internal combustion engines.

10a. State **two** reagents required to convert vegetable oil to biodiesel. *[2 marks]*

10b. Deduce the formula of the biodiesel formed when the vegetable oil shown is reacted with the reagents in (a). *[1 mark]*

10c. Explain, in terms of the molecular structure, the critical difference in properties that makes biodiesel a more suitable liquid fuel than *[2 marks]* vegetable oil.

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10d. Determine the specific energy, in $kJ\,g^{-1}$, and energy density, in $kJ\,cm^{-3}$, of a particular biodiesel using the following data and   *[2 marks]* section 1 of the data booklet.

Density = $0.850\,g\,cm^{-3}$; Molar mass = $299\,g\,mol^{-1}$;

Enthalpy of combustion = $12.0\,MJ\,mol^{-1}$.

Specific energy:

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Energy density:

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11. Vision is dependent on retinol (vitamin A) present in retina cells. Retinol is oxidized to the photosensitive chemical 11- *cis*-retinal *[2 marks]* and isomerizes to 11-*trans*-retinal on absorption of light.

Outline how the formation of 11-*trans*-retinal results in the generation of nerve signals to the brain.

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A polarimeter can be used to determine the optical rotation of an optically active substance.

12a. Describe what happens to plane-polarized light when it passes through a solution of an optically active compound. *[1 mark]*
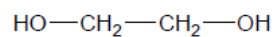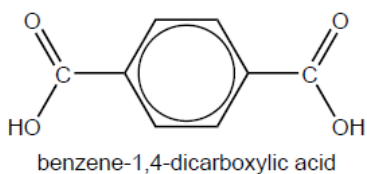
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12b. A mixture of enantiomers shows optical rotation. *[1 mark]*

Suggest a conclusion you can draw from this data.

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Antimony oxide is widely used as a homogeneous catalyst for the reaction of benzene-1,4-dicarboxylic acid with ethane-1,2-diol in the production of polyethylene terephthalate (PETE).

benzene-1,4-dicarboxylic acid

$HO\!-\!CH_2\!-\!CH_2\!-\!OH$

ethane-1,2-diol

13a. Deduce the repeating unit of the polymer and the other product of the reaction. [2 marks]

Repeating unit:

Other product:

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13b. State the class of polymer to which PETE belongs. [1 mark]

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Ethanol is a depressant that is widely consumed in many societies. When consumed excessively it has a major impact on families and society as a whole. Other depressants such as diazepam (Valium®) may be prescribed by a doctor.

One problem associated with ethanol consumption is an increased risk of traffic accidents. Police in many countries use a breathalyser to test drivers. The breathalyser contains potassium dichromate(VI).

14a. Describe the colour change of potassium dichromate(VI) when it reacts with ethanol. [1 mark]
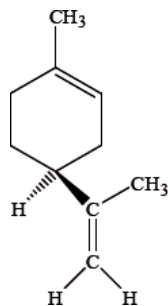
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14b. State with a reason whether chromium in potassium dichromate(VI) is oxidised or reduced by ethanol. [1 mark]

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Different conventions are used to classify enantiomers. Orange and lemon peel each contain different enantiomers of the compound limonene. One of the enantiomers is represented below.

15a. Identify the chiral centre in this enantiomer with an asterisk, *. [1 mark]

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15b. The $(+)d$-enantiomer has the characteristic smell of oranges and the $(-)l$-enantiomer has the characteristic smell of lemons. [1 mark]
Explain the meaning of the $(+)d$ and $(-)l$ symbols used in this notation.

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15c. The R, S notation is also used. The $(+)d$-enantiomer is often described as R-limonene and the $(-)l$-enantiomer as S-limonene. *[2 marks]*
Explain what is meant by the R, S notation and state whether the structure shown is R or S.

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