Class 11 Chemistry · Chapter 9: Hydrocarbons

Answer key and marking scheme · 20 marks · about 40 minutes · based on NCERT

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1. Which of the following molecular formulae can belong to an alkane? [1]

(a) C_6H_{10} (b) C_8H_{18}
(c) C_9H_{18} (d) C_7H_{14}

Answer: (b) Alkanes have the general formula C_nH_{2n+2}; for n = 8 this is C_8H_{18}. C_7H_{14} and C_9H_{18} fit C_nH_{2n} and C_6H_{10} fits C_nH_{2n-2}.

2. Which of the following alkanes contains a quaternary (4°) carbon atom? [1]

(a) 2-methylpentane (b) 3-methylpentane
(c) 2,3-dimethylbutane (d) 2,2-dimethylbutane

Answer: (d) In 2,2-dimethylbutane, $CH_3–C(CH_3)_2–CH_2–CH_3$, carbon 2 is bonded to four carbon atoms, so it is quaternary. The other three have at most tertiary carbons (bonded to three carbons).

3. Which of the following is a chain-propagation step in the chlorination of methane? [1]

(a) $\dot{C}H_3 + Cl–Cl \rightarrow CH_3–Cl + \dot{C}l$ (b) $Cl–Cl \rightarrow 2\dot{C}l$
(c) $\dot{C}H_3 + \dot{C}l \rightarrow CH_3–Cl$ (d) $\dot{C}H_3 + \dot{C}H_3 \rightarrow CH_3–CH_3$

Answer: (a) A propagation step consumes one free radical and produces another, so the chain continues: the methyl radical takes a chlorine atom and releases $\dot{C}l$. Homolysis of Cl_2 is initiation; the two radical–radical combinations remove radicals and are termination steps.

4. Methane cannot be prepared by Kolbe's electrolytic method because [1]

(a) methane is oxidised to carbon dioxide at the anode (b) acetate ions do not lose electrons at the anode
(c) the alkane is formed by joining two alkyl free radicals, so it has at least two carbon atoms (d) methane is formed at the cathode along with hydrogen

Answer: (c) At the anode carboxylate ions lose electrons, give alkyl free radicals and CO_2, and two radicals combine. Even the smallest radical, $\dot{C}H_3$, gives $CH_3–CH_3$; methane is not formed.

5. The correct order of increasing boiling point is [1]

(a) 2,2-dimethylpropane < 2-methylbutane < butane < pentane (b) butane < 2,2-dimethylpropane < 2-methylbutane < pentane
(c) 2,2-dimethylpropane < butane < 2-methylbutane < pentane (d) butane < pentane < 2-methylbutane < 2,2-dimethylpropane

Answer: (b) Among the C_5H_{12} isomers branching lowers the boiling point: pentane 309.1 K, 2-methylbutane 300.9 K, 2,2-dimethylpropane 282.5 K. Butane (molar mass 58 u) boils at 272.4 K, below even the most branched pentane, because the larger molecular mass outweighs the effect of branching here.

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6. Using $\Delta_c H^\circ$ (CH_4) = −890 kJ mol^{-1} and $\Delta_c H^\circ$ (C_4H_{10}) = −2875.84 kJ mol^{-1}, show which fuel releases more heat per gram on complete combustion. (C = 12 u, H = 1 u) [2]

Molar masses: CH_4 = 16 g mol^{-1}, C_4H_{10} = 58 g mol^{-1}. Heat per gram: methane 890 / 16 = 55.6 kJ g^{-1}; butane 2875.84 / 58 = 49.6 kJ g^{-1}. Methane releases more heat per gram, although butane releases more per mole.

- both molar masses and the two values per gram (1)
- methane releases more per gram (1)

7. Write the electrophile, and the equation for its formation, in (i) the chlorination of benzene with anhydrous $AlCl_3$ and (ii) the Friedel–Crafts acylation of benzene with ethanoyl chloride. [2]

(i) $Cl–Cl + AlCl_3 \rightarrow Cl^+ + [AlCl_4]^-$; electrophile Cl^+, the chloronium ion. (ii) $CH_3COCl + AlCl_3 \rightarrow CH_3–C^+=O + [AlCl_4]^-$; electrophile CH_3C^+O, the acylium ion. In both the Lewis acid $AlCl_3$ takes a chloride ion.

- Cl^+ with its equation (1)
- acylium ion CH_3C^+O with its equation (1)

8. The conformations of ethane cannot be separated, but cis- and trans-but-2-ene can. Explain. [2]

Rotation about the C–C single bond of ethane is hindered only by about 12.5 kJ mol^{-1}, which collisions at ordinary temperature supply, so the conformations keep changing into one another. Rotation about C=C would require the sideways overlap of the p orbitals, the π bond, to break; rotation is restricted, so the cis and trans forms do not interconvert and can be separated.

- small barrier in ethane: conformers interconvert (1)
- restricted rotation about C=C (π bond must break) (1)

9. Starting from sodium propanoate, CH_3CH_2COONa, show how you would obtain (i) ethane, (ii) chloroethane and (iii) butane, giving the reagent and conditions for each step. [3]

(i) Heat with soda lime (NaOH + CaO): $CH_3CH_2COONa + NaOH \rightarrow_{(CaO,\ \Delta)} CH_3–CH_3 + Na_2CO_3$ (decarboxylation, one carbon fewer). (ii) Chlorinate the ethane in light: $CH_3–CH_3 + Cl_2 \rightarrow_{(hv)} CH_3CH_2Cl + HCl$. (iii) Wurtz reaction on chloroethane: $2CH_3CH_2Cl + 2Na \rightarrow_{(\text{dry ether})} CH_3CH_2CH_2CH_3 + 2NaCl$.

- soda lime decarboxylation to ethane (1)
- Cl_2 in light to chloroethane (1)
- Na in dry ether to butane (1)

10. Write the structure and name of the main product when but-1-ene reacts with (i) cold concentrated sulphuric acid, (ii) water containing a few drops of concentrated sulphuric acid, (iii) bromine in carbon tetrachloride. State which of these additions follow the Markovnikov rule. [3]

(i) $CH_3CH_2CH(OSO_2OH)CH_3$, butan-2-yl hydrogen sulphate (sec-butyl hydrogen sulphate). (ii) $CH_3CH_2CH(OH)CH_3$, butan-2-ol. (iii) $CH_3CH_2CHBr–CH_2Br$, 1,2-dibromobutane. In (i) and (ii) the negative part (−OSO_2OH, −OH) goes to C2, the carbon with fewer hydrogens: Markovnikov. In (iii) both added atoms are the same, so the rule does not apply.

- (i) butan-2-yl hydrogen sulphate (1)
- (ii) butan-2-ol (1)
- (iii) 1,2-dibromobutane and the Markovnikov statement (1)

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11. The Kekulé structure of benzene predicts two different 1,2-dibromobenzenes and two different C–C bond lengths. State what is actually observed in each case and how the resonance (delocalised) picture accounts for both. [3]

Only one 1,2-dibromobenzene is known, whereas a fixed Kekulé structure would allow one with a double bond and one with a single bond between the two Br-bearing carbons. X-ray diffraction shows all six C–C bonds equal, 139 pm, between 154 pm (single) and 133 pm (double). In the resonance picture each p orbital overlaps equally with both neighbours, so the six π electrons are delocalised over the ring: every C–C bond is identical, hence one ortho isomer and one bond length.

- only one 1,2-dibromobenzene (1)
- all C–C bonds 139 pm (1)
- delocalisation makes all bonds equivalent (1)

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