1. (a) (i) fractional distillation or fractionation 1
   (ii) C₉H₂₀ only 1
   (iii) C₁₁H₂₄ + 17O₂ → 11CO₂ + 12H₂O 1
   (iv) C₁₁H₂₄ + 6O₂ → 11C + 12H₂O 1

   (b) (1) C₁₀H₂₂ → C₃H₆ + C₇H₁₆ 1
   (ii) correctly drawn structure of methylpropene
       (insist on clearly drawn C-C and C=C bonds) 1

   (c) Any two from 2
       o chemically similar or chemically the same or react in the same way
       o same functional group
       o same general formula
       o differ by CH₂

           (penalise same molecular formula or same empirical formula)

2. (a) (i) any two from:
       show a gradation/trend/gradual change in physical properties/
       a specified property
       differ by CH₂
       chemically similar or react in the same way
       have the same functional group

           (penalise 'same molecular formula')
           (penalise 'same empirical formula') 2

       (ii) fractional distillation or fractionation 1

       (iii) contains only single bonds or has no double bonds

           (credit 'every carbon is bonded to four other atoms' provided
            it does not contradict by suggesting that this will always be H) 1

   (b) (i) the molecular formula gives the actual number of atoms of each
         element/type in a molecule/hydrocarbon/compound/formula

           (penalise 'amount of atoms')
           (penalise 'ratio of atoms') 1

       (ii) C₁₄H₃₀ only

           (penalise as a contradiction if correct answer is accompanied
            by other structural formulae) 1

       (iii) C₁₀H₂₂ + 5½O₂ → 10C + 11H₂O
            (or double this equation) 1
(c) (i) \( \frac{1}{2}N_2 + \frac{1}{2}O_2 \rightarrow NO \)
(or double this equation)

(ii) Platinum or palladium or rhodium

(iii) \( 2CO + 2NO \rightarrow 2CO_2 + N_2 \) or
\( 2NO \rightarrow N_2 + O_2 \) or
(ignore extra \( O_2 \) molecules provided the equation balances)
\( C + 2NO \rightarrow CO_2 + N_2 \)
(or half of each of these equations)
\( C_8H_{18} + 25NO \rightarrow 8CO_2 + 12\frac{1}{2}N_2 + 9H_2O \)
(or double this equation)

3. (a) \( C \frac{22.24}{12} = 1.85 \quad H \frac{3.71}{1} = 3.71 \quad Br \frac{74.05}{79.9} = 0.927 \)
ratio C:H:Br = 2:4:1 \( \therefore C_2H_4Br \) (1)
empirical mass = 107.9 \( \therefore \) mol formula = \( \frac{215.8}{107.9} \times C_2H_4Br = C_4H_8Br_2 \) (1)
must use \% to justify answer

or
\( C \) \( \frac{22.24}{100} \times 215.8 = 47.99 \) i.e. \( \frac{48}{12} = 4 \) carbon atoms (1)
\( H \) \( \frac{3.71}{100} \times 215.8 = 8.01 \) i.e. \( \frac{8}{1} = 8 \) hydrogen atoms (1)
\( Br \) \( \frac{74.05}{100} \times 215.8 = 159.8 \) i.e. \( \frac{159.8}{79.9} = 2 \) bromine atoms (1)

or
\( C \) \( \frac{48}{215.8} \times 100 = 22.24\% \) (1)
\( H \) \( \frac{8}{215.8} \times 100 = 3.71\% \) (1)
\( Br \) \( \frac{159.8}{215.8} \times 100 = 74.05\% \) (1)

(b) any two pairs of marks
1,1-dibromo-(2-)methylpropane (1)
graphical formula to suit \( (CH_3)_2CHCHBr_2 \) (1)
1,2-dibromo-(2-)methylpropane (1)
graphical formula to suit \( (CH_3)_2C(Br)CH_2Br \) (1)
1,3-dibromo-(2)-methylpropane (1)
graphical formula to suit \( BrCH_2CH(CH_3)CH_2Br \) (1)
allow unambiguous names
mark name and structure independently
accept order of bromo / methyl reversed
penalise once for each of
numbering from wrong end and di in dibromo omitted max 4
4.  
(a) 2-bromo-3-methylbutane  
correct spelling each of bromo, methyl and butane (1)  
for numbers – 2 & 3 either order (1)  

(b) compounds with the same molecular formula / compounds or molecules  
not atoms or elements instead of compounds (1)  
different structural formulae / different arrangement of atoms / different  
structures / different graphical (displayed) formulae / functional groups in  
different places (1)  

5.  
1(-)bromobutane  
correct structure for 1-bromo-2-methylpropane  
(C–C bonds must be clear where drawn)  

6.  
(a) (i) compounds/mixtures/alkanes/hydrocarbons/molecules with a  
boiling point range/similar boiling point/similar number of  
carbon atoms/similar chain length;  
(insist on “similar” rather than “same”)  
(ignore references to size or \( M_r \))  
(penalise references to bond breaking/cracking as  
contradictions)  

(ii) molecules have different boiling points/intermolecular forces/sizes/chain  
lengths/\( M_r \);  
(ignore references to melting points)  
(credit the idea that molecules condense at different  
temperatures)  

(iii) the column has a higher temperature at the base (Q of L mark)  
OR  
the column has a lower temperature at the top;  
(the statement needs to be expressed in good English and show a  
clear understanding of the correct temperature difference)  
(penalise “negative OR positive temperature gradient” without  
qualification to what the candidate means, otherwise ignore)  
(ignore references to the boiling points of the molecules) (credit  
correct statements which use specific temperatures with a  
maximum temperature of 500 °C at the base)
(b) (i) \[ \text{C}_8\text{H}_{18} + 8 \frac{1}{2} \text{O}_2 \rightarrow 8\text{CO} + 9\text{H}_2\text{O}; \]
(or double this equation)

(ii) correctly drawn structure of 2,2,3-trimethylpentane
(penalise the use of ‘sticks’ once on the paper, including the structures in the 2(a)(ii) and 2(c)(iii) mechanisms) (credit correctly condensed structures)

(c) cracking produces/makes ethene/propene/alkenes/motor fuels/petrol
OR cracking makes more useful products/high(er) value products
OR cracking satisfies the high demand for small(er) products;
(ignore the idea that cracking makes or leads to plastics or polyethene) (high demand needs to be qualified)

(d) zeolite
OR aluminosilicate OR \( \text{A}_1\text{O}_3\text{I}; \)

(e) alkene(s);
(cold “small or short chain alkenes”)
(penalise “cycloalkenes”)
(penalise additional types of compounds (e.g. branched alkanes) as a contradiction)
(do not credit examples or formulae, but ignore if these are correct and in addition to the word “alkene”) [8]

7. (a) \( \text{C}_{15}\text{H}_{32} + 23 \text{O}_2 \rightarrow 15 \text{CO}_2 + 16\text{H}_2\text{O} \)
Products (1)
Balance (1)
If wrong reactant C.E

(b) Identity of product: CO or carbon monoxide (1)
Equation: \( \text{CH}_4 + \frac{3}{4} \text{O}_2 \rightarrow \text{CO} + 2\text{H}_2\text{O} \) (1)
Any balanced equation using \( \text{CH}_4 \), producing CO
Not could also make C + \( \text{CO}_2 \) [4]

8. (a) Crude oil is heated to vaporise it / oil vaporised (1)
(Vapour passed into fractionating) tower/column (1)
Top of tower cooler than bottom
or negative temperature gradient (1)
fractions separated by b.p
OR condensed at different temperatures OR levels
OR low boiling fractions at the top
OR at the top small molecules or light components (1) max 3
(b) (i) Identify shortfall in supply - e.g. petrol / small molecules (1)
Higher value products OR more useful products (1)
OR cracking produces more of material (problem solving)

(ii) Motor fuels
Aromatic hydrocarbons
Branched alkanes / hydrocarbons
Cycloalkanes
Any two (2)
Ignore specific fractions, alkanes, shorter alkenes, penalise alkenes, and hydrogen

(c) Catalyst: Zeolite / aluminosilicate (1)
Conditions: High temp OR around 450 °C [300 – 600] °C NOT heat / warm (1)
Slight pressure [> 1 atm ≤ 10 atm OR 1 megaPa, 1000 kPa] (1)
NOT high pressure

9. (a) (i) Kerosine or paraffin (1)
(ii) Boiling point (1)

(b) (i) $C_{19}H_{40}$ (1)
(ii) $C_{16}H_{34} \rightarrow 2C_2H_4 + C_3H_6 + C_9H_{20}$
or $C_{16}H_{34} \rightarrow 4C_2H_4 + 2C_3H_6 + C_2H_6$ (2)

10. but-1-ene (1)

11. (a) petrochemicals (1)
Kerosine or paraffin (1)
Power stations or ships (1)

(b) (i) \[
\begin{align*}
\text{CH}_3 \\ \\
\text{CH}_3 \\ \\
\text{CH}_3 \\ \\
\text{CH}_3 \\
\end{align*}
\]
(1)

(ii) \[
\begin{align*}
\text{CH}_3 \\
\text{C} \\
\text{CH}_3 \\
\text{CH}_3 \\
\end{align*}
\]
or \[
\begin{align*}
\text{CH}_3 \\
\end{align*}
\]
(1)

(c) (i) $C_8H_{18}$ (1)
(ii) $C_{12}H_{26}$ (1)
12. (a) (i) Gas oil or diesel (1)
(ii) \( \text{C}_{16}\text{H}_{34} \rightarrow \text{C}_{8}\text{H}_{18} + 2\text{C}_{3}\text{H}_{6} + \text{C}_{2}\text{H}_{4} \) eqn (1)
(iii) To produce polymers (1)  

(b) (i) Large surface area (1) faster reaction (1)  
(ii) \( \text{C}_{8}\text{H}_{18} + 25\text{NO} \rightarrow 8\text{CO}_{2} + 9\text{H}_{2}\text{O} + 12\frac{1}{2}\text{N}_{2} \) (2)  

13. (a) Missing fraction = naphtha (allow naphtha from list if not quoted separately) (1) Order = mineral oil (lubricating oil), gas oil (diesel), kerosene (paraffin), naphtha, petrol (gasoline) (1)  
Mark order consequential on M1 (if no missing fraction given, M2 = 0) Accept correct reversed order  
Negative temperature gradient on the column or temperature of column decreases upwards (1)  
Larger molecules or heavier fractions condense at higher temperatures or lower down the column or reference to different boiling points (ignore mp) (1)  

(b) Type of mechanism = (free) radical / homolytic fission - used in complete sentence phrase (1)  
\( \text{C}_{21}\text{H}_{44} \rightarrow 3\text{C}_{2}\text{H}_{4} + 2\text{C}_{3}\text{H}_{6} + \text{C}_{9}\text{H}_{20} \) correct alkenes (1)  
Accept \( \text{CH}_{2}\text{CH}_{2} \) & \( \text{CH}_{2}\text{CHCH}_{3} \) all correct (1)  

(c) (i) Sulphur (containing impurities) burn to form or forms \( \text{SO}_{2} \) or correct oxides of sulphur (if oxide identified, must be correct) (1)  
OR equation: e.g. \( \text{S} + \text{O}_{2} \rightarrow \text{SO}_{2} \) or \( \text{H}_{2}\text{S} + 1\frac{1}{2}\text{O}_{2} \rightarrow \text{SO}_{2} + \text{H}_{2}\text{O} \)  
Leading to acid rain (must have specified oxides of S or burning) or toxic product or respiratory problems (1)  

(ii) NO formed by reaction between \( \text{N}_{2} \) and \( \text{O}_{2} \) from the air (1)  
OR \( \text{N}_{2} + \text{O}_{2} \rightarrow 2\text{NO} \)  
High combustion temperature or spark in engine (1)  
provides \( \text{E}_{\text{A}} \) or sufficient heat / energy to break \( \text{N}≡\text{N} \) (1)  

(iii) Need to remove NO as forms acid rain or toxic product or causes respiratory problems (1)  
\( 2\text{NO} + \text{O}_{2} \rightarrow 2\text{NO}_{2} \) (1)  
\( 4\text{NO}_{2} + \text{O}_{2} + 2\text{H}_{2}\text{O} \rightarrow 4\text{HNO}_{3} \) (1)  
Need to remove CO as it is poisonous (1)
Catalytic converter (1)
uses Pt / Rh / Pd / Ir (wrong answer cancels a correct one) (1)
Provides active sites / reduces E_A (1)
Forms N_2 + CO_2 (1)
2NO + 2CO → N_2 + 2CO_2 (correct equation worth last 2 marks) (1)
Max 10

14. (a) pollutants: CO (1)
NO or NO_2 (1)
unburned hydrocarbons (1)
CO from incomplete combustion (1)
eg C_8H_18 + 8 \frac{1}{2} O_2 → 8CO + 9H_2O (eqn 1)
NO from N_2 + O_2 → 2NO (1)
spark (1) max 7
removal: reaction between NO_x and CO or C_xH_y to form harmless products (1)
eqn : 2NO + 2CO → N_2 + 2CO_2 (2)
C_8H_18 + 25NO → 8CO_2 + 9H_2O + 12\frac{1}{2}N_2 (2)
one of Pt/Rh/Pd catalyst (1) max 4
(b) Demand for heavy fraction: low or for petrol: high (1)
Supply of heavy fraction: high or of petrol: low (1)
larger Mr are less volatile/have higher bp (1)
due to stronger intermolecular forces (1) 4

15. Cracking (1)
radical mechanism (1)
Any two equations e.g
C_{10}H_{22} → C_2H_4 + C_8H_{18}
C_{10}H_{22} → 2C_2H_4 + C_6H_{14} (2)
C_{10}H_{22} or larger alkanes: low demand/high abundance/less useful (1)
C_2H_4 or smaller alkanes: high demand/low abundance/more useful (1)
Uses: ethene to make polymers/plastics/ethanol (1)
octane or smaller alkanes - for petrol or fuels (1) 8
16. (a) heated / vaporised / boiled
passed into column / tower
condense at different heights / liquefy at different heights
similar molecules (size, bp, mass) condense together / (1)
small molecules at the top and big molecules at the bottom 4

(b) larger (1)
reduces decomposition (1) 2

(c) (i) hexane or valid isomers (1)
propene (1) 2
(ii) C₃H₆ (1) 1

(d) CHCl₃ (1)
C₂HBrClF₃ or correct structural formula (1)

[11]