1. Bond breaking absorbs energy
AND bond making releases energy ✓

ALLOW *bond breaking is endothermic*
AND *bond making is exothermic*

More energy released than absorbed ✓

ALLOW *exothermic change transfers more energy than endothermic change*
OR *bond making transfers more energy than bond breaking*
OR *'(the sum of the) bond enthalpies in the products is greater than the (sum of the) bond enthalpies in the reactants'*
OR *'(the sum of the) bond enthalpies of the bonds made is greater than (the sum of) the bond enthalpies of the bonds broken'*

IGNORE *reference to strong and weak bonds*

IGNORE *enthalpy of products is less than enthalpy of reactants*

[2]

2. Respiration ✓

IGNORE *anaerobic*

[1]

3. (i) $100 \times 4.18 \times 17.3$ ✓

ALLOW *7231 J* ✓

7.23 (kJ) ✓

ALLOW *7.23 with no working out*
ALLOW *from 7.2 up to calculator value of 7.2314*

ALLOW *from 0.060 up to calculator value for 1 mark (i.e. ECF from use of m = 0.831 in first stage)*

IGNORE *sign*

2

(ii) $M_r = 180$ ✓

amount = 4.62×10^{-3} (mol) ✓

ALLOW *4.6×10^{-3}* ***OR*** *4.62×10^{-3}*

OR *4.617×10^{-3} up to calculator value*
DO NOT ALLOW *0.005*
ALLOW *ECF from wrong M_r*

2

(iii) ΔH_c = 1560 (kJ) **OR** 1570 (kJ)
but answer must be to 3 sig fig ✓

ALLOW *ECF from 'answer to* ***(i)*** *÷ answer to* ***(ii)****'*
but answer must be to 3 sig fig

minus sign ✓

minus mark is an independent mark

2

[6]

4. +1250 ✓

ALLOW *full marks for −2830 with no working out* ✓✓✓

+(−394 × 6) + (−286 × 6) **OR** –4080 ✓
−2830 ✓

ALLOW for 2 marks:

+2830	*cycle wrong way around*
OR *1400* ***OR*** *860*	*one value not × 6*
OR *–5330* ***OR*** *+5330*	*wrong sign for 1250 or 4080*
OR *+570* ✓✓	*correct cycle but not × 6*

ALLOW for 1 mark:

–1400 ***OR*** *– 860*	*cycle wrong way around and one value not × 6*
OR *–570*	*cycle wrong way around and not × 6*
OR *–1930 OR +1930* ✓	*wrong sign and not × 6*

Note: *There may be other possibilities.*

[3]

5. **Any two from the following:**

Heat released to the surroundings ✓

ALLOW *heat loss*

Incomplete combustion **OR** incomplete reaction
OR not everything burns

IGNORE *reference to evaporation*

Non-standard conditions ✓

[2]

6. (i) Acid ✓

ALLOW *correct formula if no name given:*
e.g. H_3PO_4 ***OR*** H_2SO_4 ***OR*** H^+ ✓

ALLOW *correct name of acid even if an incorrect formula is used*

IGNORE *heterogeneous* ***OR*** *homogeneous*

1

(ii) The position of equilibrium will shift so as to minimise the effect of any change in conditions ✓

DO NOT ALLOW *'reaction shifts'*
The idea of a shift in equilibrium is essential

1

(iii) Low temperature **AND** high pressure ✓

One mark for conditions.
This mark is independent of the reasons for conditions

Low temperature because the (forward) reaction is exothermic ✓

One mark for reason for the chosen temperature

High pressure because there are fewer moles (of gas) on the right hand side ✓

One mark for reason for the chosen pressure
ALLOW *fewer moles of products*

3

(iv) (60 atmosphere pressure is a) high pressure may be too expensive **OR** may cause safety problems ✓

(300 °C is sufficiently high) to give a fast rate of reaction ✓

without shifting equilibrium to the left
OR compromising equilibrium yield ✓

3

[8]

7. The enthalpy change for the complete combustion ✓

of 1 mol (of a substance) ✓

ALLOW *energy change for combustion in excess oxygen* ***OR*** *energy released during complete combustion* ***OR*** *energy change for combustion in excess air*
NOT *energy required*

This mark is not stand alone but must relate to statement about an enthalpy change even if the statement was not awarded a mark

[2]

8. (i) 56.430 (kJ) ✓

ALLOW *56.43 (kJ)* ***OR*** *56.4 kJ* ✓ ***OR*** *56 kJ*
ALLOW *-56.43 i.e. ignore sign*

1

(ii) M_r [$CH_3(CH_2)_4OH$] = 88.0 ✓

n = 0.0200 mol ✓

ALLOW *88*

ALLOW *0.02* ***OR*** *ecf from wrong* M_r

ALLOW *full marks for 0.02 with no working out*

2

(iii) (–)2821.5 ✓

= (–)2820 (3 SF) ✓

correct minus sign ✓

ALLOW correct substitution into formula*(b)(i) ÷ (b)(ii) e.g. 56.4 ÷ 0.02 this is essentially a mark for the working*

ALLOW *ecf from i.e. answer from (b)(i) ÷ (b)(ii)*

The minus mark is stand alone and is independent of the numerical answer

3

[6]

9. (i) pressure: 100 kPa **OR** 101 kPa
AND
temperature: 298 K **OR** 25°C ✓

units needed

ALLOW *1 bar* ***OR*** *1 atm* ***OR*** *760 mmHg*

ALLOW *any stated temperature so for example 100kPa and 40°C would be credited with a mark*

IGNORE *any reference to moles or concentration*

1

(ii) $6C(s) + 7H_2(g) \rightarrow C_6H_{14}(l)$ ✓

ALLOW *graphite / gr*

1

(iii) many different hydrocarbons would form
OR activation energy too high
OR reaction too slow
OR they don't react together ✓

ALLOW *can form different isomers* ***OR*** *can form different structures*

IGNORE *reaction may be reversible*

1

(iv) $6 \times -394 + 7 \times -286$ shown **OR** calculated as –4366 ✓

–4366 and –4163 added **OR** subtracted ✓

correct answer $-4366 - (-4163) = -203$ ✓

ALLOW THREE *marks for –203 on its own with no working out or written on the answer line*

ALLOW TWO *marks for +203,+3483, +1513, +1767 or –8529 on its own with no working out*

ALLOW ONE *mark for –3483, –1513, –1767 or +8529 on its own with no working out*

units ***NOT*** *needed*

Positive sign not needed for endothermic answers

3

[6]

10. (i) $Cl + O_3 \rightarrow ClO + O_2$ ✓
$ClO + O \rightarrow Cl + O_2$ ✓
overall: $O_3 + O \rightarrow 2O_2$ ✓

OR

$Cl + CH_4 \rightarrow CH_3 + HCl$ ✓
$CH_3 + Cl_2 \rightarrow CH_3Cl + Cl$ ✓
overall: $CH_4 + Cl_2 \rightarrow CH_3Cl + HCl$ ✓

Marks must come from one or other of the radical process and not from both of them.
If two processes are described then an incorrect step in one process will contradict a correct step in the other process.

ALLOW *overall equation mark even if the steps are wrong*
the radicals do ***NOT*** *need a single dot*
IGNORE *any state symbols*

ALLOW
$Cl + O_3 \rightarrow ClO + O_2$ ✓
$ClO + O_3 \rightarrow Cl + 2O_2$ ✓
overall: $2O_3 \rightarrow 3O_2$ ✓

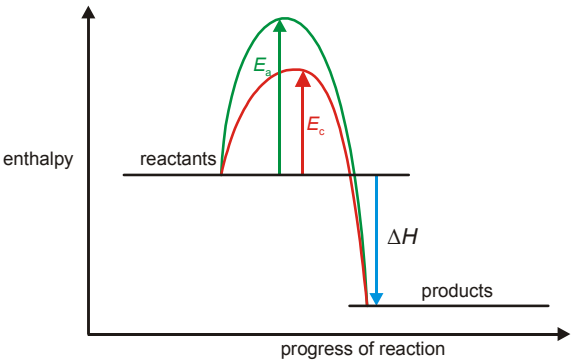
ALLOW *any saturated hydrocarbon including cyclic*
ALLOW *ecf for second step and overall reaction if wrong hydrocarbon used e.g. C_2H_4 is used in first step*

3

(ii) ΔH shown **and** products below reactants ✓

E_a shown ✓

E_c shown < E_a ✓



***NOT** double headed arrows but apply ecf for more than one double headed arrow*

***ALLOW** one mark if two correctly labelled curves are drawn but the arrows are not shown or are incorrectly drawn*
The arrows must be positioned as closely as possible to the maximum height of the curves but allow some degree of bod

3

[6]

11. (i) bond breaking is endothermic/
energy has to be put in to break a bond **(1)** 1

(ii) bonds broken: 3(C–H) + (C–O) + (O–H) + 1.5 (O=O) = 2781 kJ **(1)**
bonds made: 2(C=O) + 4(O–H) = 3470 kJ **(1)**
ΔH_c = –689 (kJ mol^{-1}) **(1)** 3

[4]

12. (a) (i) (heat/energy change) when 1 mole of substance is formed **(1)**
from its elements **(1)** 2

(ii) 1 atm/101 kPa and a stated temperature/25 °C/298 K **(1)** 1

(iii) $C(s) + ½ O_2(g) \rightarrow CO(g)$ 2
balanced equation forming 1 mol CO **(1)**
state symbols **(1)**

(iv) cycle drawn/sum of ΔH(products) – ΔH(products) **(1)**
$–75 – 242 + x = –110$ **(1)**
$\Delta H = (+)207$ kJ mol^{-1} **(1)** 3

(b) production of margarine/ammonia/Haber process **(1)** 1

[9]

13. $C_3H_8 + 5O_2 \rightarrow 3CO_2 + 4H_2O$

formulae ✓
balancing ✓
ignore state symbols

[2]

14. (enthalpy/ energy/ heat change) when 1 mole of substance/
element/ compound ✓ (NOT absorbed)
is completely burnt/ burnt in excess oxygen ✓
under standard conditions (if conditions stated they must be
correct) ✓

[3]

15. (i) (enthalpy change) when 1 mole of compound is formed ✓
from the constituent elements ✓ 2

(ii) $6C(s) + 7H_2(g) \rightarrow C_6H_{14}(l)$
correct formulae and balancing ✓
tate symbols ✓ 2

(iii) temperature 25°C/ 298K/ a stated temperature (if justified)
pressure 1 atm/ 100 kPa/ 101 kPa ✓ 1

[5]

16. diagram to show
lines to show energy level at start above that at end of reaction ✓
ΔH labelled between reactants and products ✓
E_a labelled from reactants to top of energy 'hump' ✓

[3]

17. correct Hess' cycle ✓
$x - 890 = -572 - 394$ ✓
$x = -76$ (kJ mol^{-1}) ✓

[3]

18. (i) $1652/4 = 413$ (kJ mol^{-1}) ✓ 1

(ii) (C□C) + 6 (C□H) = 2825 ✓
(C□C) = 2825 – 6(413) = 347 (kJ mol^{-1}) ✓ 2

[3]

19. (a) (a reaction) that releases energy/ (a reaction) that releases heat/ a reaction with a negative ΔH (1) 1

(b) (i) diagram to show
upward **hump** (1)
$CO_2 + (2)H_2O$/ carbon dioxide and water below reactants (1) 2

(ii) E_a marked (1)
if an arrowhead is included, it must be upwards 1

[4]

20. (a) (heat/ energy change) when 1 mole of substance is formed (1)
from its elements (1) 2

(b) $C(s) + 2H_2(g) \rightarrow CH_4(g)$
balanced equation (1)
state symbols (1) 2

(c) cycle drawn/ sum of enthalpy changes products – sum of enthalpy changes reactants (1)
$-75 - 242 + \times = -110$ (1)
$\Delta H = 207$ (kJ mol^{-1}) (1) 3

(d) any industrial use, examples include
manufacture of ammonia/ for Haber process
manufacture of margarine/ hydrogenation of alkenes 1

[8]

21. (i) to break a bond energy has to be put in/ ✓
breaking bonds is endothermic 1

(ii) energy needed to break 1 mole **of bonds** ✓
in the **substance** in the gaseous state ✓ 2

(iii) bonds broken:
3(C–H) + (C–O) + (O–H) + 1½ (O=O) = 2781 kJ ✓
bonds made:
2(C=O) + 4(O–H) = 3470 kJ ✓
$\Delta H_c = -689$ ✓ (kJ mol^{-1}) 3

(iv) actual bond enthalpies may be different from average values ✓
conditions are not standard / methanol/ water is a liquid under standard conditions ✓ 2

[8]

22. (i) (enthalpy/ energy change) when 1 mole of substance/compound formed ✓
from its elements ✓
under standard conditions ✓ (if conditions quoted must be correct – 25 C/298 K, 1 atm/100 kPa/101 kPa) 3

(ii) $Mg(s) + N_2(g) + 3O_2(g)$ ✓ $Mg(NO_3)_2(s)$
balanced species ✓
state symbols ✓ 2

(iii) cycle ✓
$x - 791 = -602 - 2(33)$ ✓
$x = 123$ ✓ 3

[8]

23. (i) reaction carried out at 298K and 1 atm pressure (or other relevant units) (1) 1

(ii) enthalpy change when 1 mole (1)
(of substance) is burnt in excess oxygen (1) 2

(iii) $4CO_2 + 5H_2O$ at lower energy than reagents (1)
E_a marked correctly (1)
ΔH marked correctly (1) 3

[6]

24. (i) $4C(s) + 5H_2(g) \rightarrow C_4H_{10}(g)$
reagents and products (1)
state symbols (1) 2

(ii) $4C + 5H_2 \xrightarrow{X} C_4H_{10}$
$4(-394)\ 5(-286)\ -2877$
$4CO_2\ 5H_2O$
cycle (1)
correct values (1)
answer (1)
$X - 2877 = 4(-394) + 5(-286)$
$X = -129$ (kJ mol^{-1}) 3

[5]

25. (a) (i) bonds broken
(N — N) + (O == O) + (N — H) = 163 + 497 + 4(390) = 2220 (kJ mol^{-1}) (1)
bonds made
$(N \equiv N) + 4(\tilde{OH}) = 945 + 4(463) = 2797\ (KJ\ mo\tilde{l}^{1})$ (1)
broken ΔH is +ve and made ΔH is −ve (1)
enthalpy of reaction $\tilde{=}$ $577\ (KJ\ mo\tilde{l}^{1})$ (1) 4

(ii) $\frac{577}{32} = 18.0(KJ)$ (1) 1

(b) N-N bond is weak/ higher Ea for ammonia/ rate too slow for ammonia/ too much energy to break bonds in ammonia / hydrazine is liquid/ do not need pressurised containers/ more moles/ lots of gas produced by hydrazine/ more energy per mole produced by hydrazine (1) 1

[6]

26. (a) (enthalpy change) when 1 mole of substance/ element/ compound (1)

NOT energy needed

is completely burnt (1) 2

(b) $C_3H_7OH(l) + 4\frac{1}{2}\ O_2(g) \rightarrow 3CO_2(g) + 4H_2O(I)$

correctly balanced equation (1)

state symbols (species must be correct) (1) 2

(c) (i) $\Delta H = mc\Delta T$ (1)

$\Delta H = 50 \times 4.18 \times 12.8 = 2675$ (J) = 2.68 (kJ) (1) 2
ignore sign

(ii) Mr propan-1-ol = 60 (1)

number moles = 0.00167 (1) 2

(iii) $\Delta H = \tilde{(}1608(KJ\ mo\tilde{l}^{1})$ (1) 1

(iv) heat losses (1)

thermal capacity of beaker ignored (1)

conditions were non-standard (1)

combustion could be incomplete (1)

propan-1-ol evaporates (1)

water evaporates (1) 2

[11]

27. (i) the enthalpy change when <u>1 mole</u> of compound/species/substance is formed ✓
[mention of 1 mole of *elements* negates this mark]

from its <u>elements</u> [NOT atoms/ions] (under standard conditions) ✓ 2

(ii) 25°C/298K **and** 1 atmos/1×10^5 Pa ✓ 1

[3]

28. $Pb(s) + ½ O_2(g) \rightarrow PbO(s)$ *(balancing for 1 mol of PbO)* ✓

(state symbols) ✓u/c

[2]

29. (i) $\Delta H^{\Theta}_f = -718 - 3(-217)$

$= \mathbf{-67}$ (kJ mol^{-1}) (*use of correct data & multiplier* ✓)

(correct signs ✓*)*

(correct calculation of value ✓*)* 3

some possible ecf values: +67 2

–501 2

+501 1

–1369 2

+1369 1

(ii) $\Delta H^{\Theta}_f = -718 + 10 + 2(217)$

$= \mathbf{-274}$ (kJ mol^{-1}) *(use of correct data & multiplie* ✓*)*

(correct signs ✓*)*

(correct calculation of value ✓*)* 3

some possible ecf values: -57 [2]

–284 [2] –294 [2]

+424 [1] +444 [2] –491 [2]

–511 [1] –708 [1] –1142 [2]

for others, work through the calc: –[1] for each error.

[6]

30. I-I(g) → 2I(g) *(state symbols ✓)*
(1 mole I_2 ✓)

[2]

31. No mark scheme available

32. No mark scheme available

33. No mark scheme available