1. (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]

2. (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)**
ΔH = (+)207 kJ mol^{-1} **(1)** 3

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

[9]

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

formulae ✓
balancing ✓
ignore state symbols

[2]

4. (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]

5. (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]

6. 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]

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

[3]

8. (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]

9. (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]

10. (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) 3
$\Delta H = 207$ (kJ mol^{-1}) (1)

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

[8]

11. (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]

12. (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]

13. (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]

14. (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]

15. (a) (i) bonds broken

$(N — N) + (O == O) + (N — H) = 163 + 497 + 4(390) = 2220$ (kJ mol^{-1}) (1)

bonds made

$(N \equiv N) + 4(\tilde{O}H) = 945 + 4(463) = 2797$ $(KJ\ mo\tilde{l}^{1})$ (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]

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

NOT energy needed

is completely burnt (1) 2

(b) $C_3H_7OH(l) + 4½\ O_2(g) \rightarrow 3CO_2(g) + 4H_2O(I)$

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]

17. (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]

18. $Pb(s) + \frac{1}{2} O_2(g) \rightarrow PbO(s)$ *(balancing for 1 mol of PbO)* ✓

(state symbols) ✓u/c

[2]

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

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

= **-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]

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

[2]

21. No mark scheme available

22. No mark scheme available

23. No mark scheme available