



**EXAM PAPERS PRACTICE**

Boost your performance and confidence  
with these topic-based exam questions

Practice questions created by actual  
examiners and assessment experts

Detailed mark scheme

Suitable for all boards

Designed to test your ability and  
thoroughly prepare you

2002

**XVIII**

1583

Time allowed  
**231 Minutes**

**Score**

**/193**

**Percentage**

**%**

**CHEMISTRY**

**AQA  
AS & A LEVEL**

**Mark Scheme**

**3.1 Physical chemistry**

- 1 (a)  $\Delta H = \Sigma \Delta H_f \text{ products} - \Sigma \Delta H_f \text{ reactants}$  or cycle (1)  
 $= [(3 \times -393) + (3 \times -242)] - [+53]$  (1)  
 $= -1905 - 53$   
 $= -1958 \text{ kJ mol}^{-1}$  (1) 3
- (b) The enthalpy required to break a covalent bond (1)  
 average over a wide range of compounds (1) 2
- (c) In;  $3 \times \text{C-C}; 3 \times 347 = +1041$   
 $6 \times \text{C-H}; 6 \times 413 = +2478$   
 $4.5 \times 0 = 0; 4.5 \times 498 = +2241$   
 Total in + 5760 (1)  
 Out;  $6 \times \text{C=O}; 6 \times -805 = -4830$   
 $6 \times \text{O-H}; 6 \times -464 = -2784$   
 Total out -7614 (1)  
 Enthalpy change =  $5760 - 7614 = -1854 \text{ kJ mol}^{-1}$  (1) 3
- (d) Cyclopropane has a strained ring structure (1)  
 Bonds in cyclopropane are weaker OR  
 Bond enthalpies depend on environment OR  
 Mean bond enthalpies used in the calculation (1) 2

[10]

2

- (a) *Standard enthalpy of formation* The enthalpy change when one mole of a compound (1) is formed from its constituent element (1) in their normal or standard state (1) under standard conditions

*Standard enthalpy of combustion* The enthalpy change when one mole of a compound (1) is completely burnt in oxygen (1) under standard condition or at 298K and 100kPa (1)

6

- (b)  $\Delta H = \sum \Delta H_f \text{ products} - \sum \Delta H_f \text{ reactants}$  or cycle (1)  
 $= 3\Delta H_f \text{CO}_2 + 4\Delta H_f \text{H}_2\text{O} - \Delta H_f \text{C}_3\text{H}_7\text{OH}$  (1)  
 $= -2022 \text{ kJ mol}^{-1}$  (1)

3

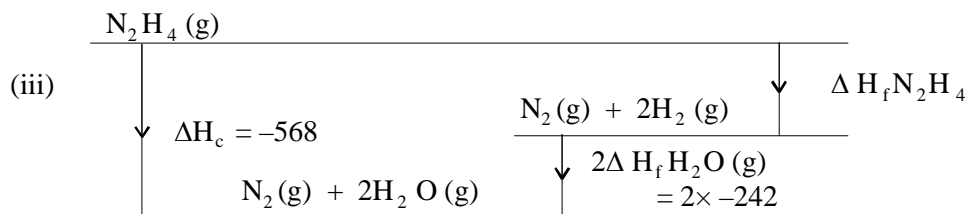
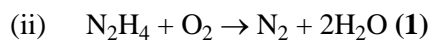
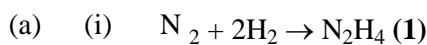
- (c) (i) Enthalpy  $= 200 \times 4.2 \times 15$  (1)  
 $= 12.6 \text{ kJ}$  (1)  
 (ii) Moles  $\text{C}_3\text{H}_7\text{OH} = 0.90/60$  (1)  
 $12.6 \text{ kJ}$  (1)  
 (iii) Enthalpy of combustion  $= -12.6/0.015$  (1)  
 $= -840 \text{ kJ mol}^{-1}$  (1)  
 (iv) *Reason 1* Incomplete combustion  
 Heat lost to surroundings  
*Reason 2* Heat capacity of the apparatus  
 Any two (2)

8

[17]

- 3 (a) enthalpy change for one mole of compound (1)  
formed from its elements (1)  
in their standard states (1) 3
- (b) by definition (1) 1
- (c)  $\Delta H = 2 \times \Delta H_f^\ominus (\text{CF}_4) + 6 \times \Delta H_f^\ominus (\text{HF}) - \Delta H_f^\ominus (\text{C}_2\text{H}_6)$  (1)  
 $= 2 \times -680 + 6 \times -269 - (-85)$  (1)  
 $= -2889$  (1) ( $\text{kJ mol}^{-1}$ ) 3
- (d) (i) bond energies (enthalpies) vary between compounds (1)  
 $\therefore$  an average value is used (1)
- (ii) *First step in the reaction* F–F bond breaks (1)  
*Reason* weakest bond (1) 4
- [11]

4



$\Delta H_f = -484 + 568 = +84 \text{ kJ mol}^{-1}$  (1)

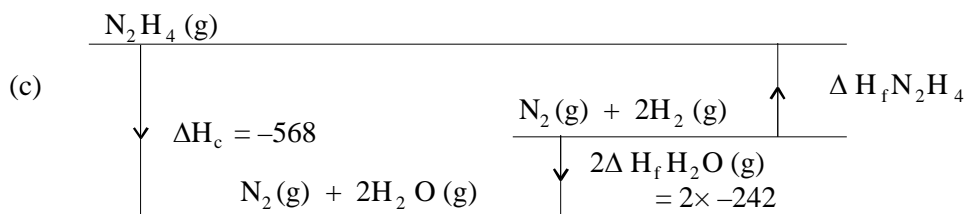
[OR  $\Delta H_f = 2\Delta H_f \text{H}_2\text{O}(\text{g}) - \Delta H_c \text{N}_2\text{H}_4$  (1) =  $84 \text{ kJ mol}^{-1}$  (1)]

4

(b) Enthalpy or heat required to break a covalent bond (1)

Average over a range of compounds

2



Hence  $(\text{N}-\text{N}) = 872 + 945 - 84 - 1556$  (1) =  $177 \text{ kJ mol}^{-1}$  (1)

Note:— Mark consequentially to  $\Delta H_f \text{N}_2\text{H}_4$  from a(iii)

3

(d) The N–H bond enthalpies used in the calculation were mean values or depend on environment (1)

1

[10]

- 5 (a) enthalpy change (1)  
independent of reaction route (1) 2
- (b) enthalpy change for 1 mol (1)  
completely burned in oxygen (1)  
under standard condition (1) 3
- (c) (i) *Equation for formation of CS<sub>2</sub>*  $\text{C(s)} + 2\text{S(s)} \rightarrow \text{CS}_2\text{(l)}$  (1)  
*Equation for combustion of CS<sub>2</sub>*  $\text{CS}_2\text{(l)} + 3\text{O}_2\text{(g)} \rightarrow \text{CO}_2\text{(g)} + 2\text{SO}_2\text{(g)}$  (1)
- (ii)  $\Delta H_f^\ominus = \Delta H_c^\ominus(\text{C}) + 2\Delta H_c^\ominus(\text{S}) - \Delta H_f^\ominus(\text{CS}_2)$  (1)  
(or correct cycle)  
 $= -394 + 2(-297) - 88$  (1)  
 $= -1076 \text{ kJ mol}^{-1}$  (1) 5
- (d)  $\Delta H^\ominus = \Delta H_f^\ominus(\text{CO}) + 2\Delta H_f^\ominus(\text{SO}_2) - (\Delta H_f^\ominus(\text{CS}_2) + 5\Delta H_f^\ominus(\text{NO}))$  (1)  
(or correct cycle)  
 $= -111 + 2(-297) - (88 + 5 \times 90)$  (1)  
 $= -1243 \text{ kJ mol}^{-1}$  (1) 3

[13]

- 6 (a) enthalpy change when 1 mol of a compound (1)  
is completely burned in oxygen (1)  
under standard conditions (1) 3
- (b)  $\text{CH}_3\text{SH} + 3\text{O}_2 \rightarrow \text{CO}_2 + 2\text{H}_2\text{O} + \text{SO}_2$  1
- (c) enthalpies of combustion of C, H<sub>2</sub>, S  
*one correct (1)*  
*three correct (2)*  
(or enthalpies of formation of CO<sub>2</sub>, H<sub>2</sub>O, SO<sub>2</sub>)  
*one correct (1)*  
*three correct (2)* 2
- (d)  $\Delta H^\ominus = -\Delta H_f^\ominus (\text{CS}_2) + \Delta H_f^\ominus (\text{CO}_2) + 2\Delta H_f^\ominus (\text{SO}_2)$  (1)  
*or cycle with the same information*  
 $= -88 - 394 - 594$  (1)  
 $= -1076 \text{ kJ mol}^{-1}$  (1)  
*+1076 scores one, -900 scores 1 cycle mark* 3

[9]

7

- (a) (The enthalpy/heat change) when one mole (1) is completely burned/combusted in oxygen/air (1)  
under standard conditions or 100K Pa/lbar/atm/760mm Hg (1) and 298K or STP  
**Penalise first mark if heat adsorped. Penalise first mark if "energy change" stated**

3

- (b)  $\Delta H_R^\ominus = \sum \Delta H_f^\ominus \text{ products} - \Delta H_f^\ominus \text{ reactants}$  or  
 $\Delta H_R^\ominus = \Delta H_f^\ominus \text{CO}_2 + 2\Delta H_f^\ominus \text{H}_2\text{O} - \Delta H_f^\ominus \text{CH}_4$  (1)  
 $= (-394) + 2(-286) - (-75)$  (1)  
 $= -891 \text{ (kJ mol}^{-1}\text{)}$   
**Allow +891 [max 1]**

3

- (c) (i) Enthalpy (Do not allow energy) required to break a covalent bond (1)  
*Allow second mark separately*  
 averaged over (many) compounds (1)  
 (ii)  $\Delta H_a = \sum \text{Bonds broken} - \sum \text{Bonds made}$  or cycle (1)

	$\text{C(g)} + 4\text{H(g)}$		
Allow -415 to -416 Max (2)	$\text{C(g)} + 2\text{H}_2\text{(g)}$	$\uparrow 2\Delta H_{\text{BE}} \text{H}_2$	
	$\text{C(s)} + 2\text{H}_2\text{(g)}$	$\uparrow \Delta H_{\text{BE}} \text{C}$	$\uparrow 4\text{BE(C-H)}$
Allow 1662 Max (1)		$\downarrow \Delta H_f \text{CH}_4$	$\text{CH}_4\text{(g)}$

$$\text{BE (C-H)} = \frac{715 + 2(436) - (-75)}{4} \text{ (1)} = 415.5 \text{ (kJ mol}^{-1}\text{)} \text{ (1)}$$

Allow 415-416

- (iii)  $4020 = 2\text{BE (C-C)} + 8\text{BE (C-H)}$  (1)  
**CE if 3BE(C-C) used**

$$\text{BE (C-C)} + \frac{4020 - 8(415.5)}{2} = 348 \text{ (kJ mol}^{-1}\text{)} \text{ (1) Allow 346-350}$$

7

**Mark conseq**

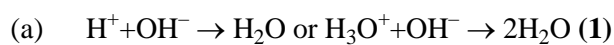
**Note: Using 390, the given answer, BE (C-C) = 450 [2]**

**The common wrong answer in C(ii) is 378 this gives BE(C-C) as 498 conseq [2]**

[13]



8



**Ignore state symbols; ignore 'spectator' ions**

1

(b)  $\text{Mol H}^+ = 50.0 \times 1.00 / 1000 = 5 \times 10^{-2}$  (1)

1

(c) Heat energy evolved =  $MC\Delta T$  / MS  $\theta$  or in words (1)

=  $100 \times 4.18 \times 6.5 = 2717$  Allow 2700 – 2717 (1)

or =  $0.1 \times 4.18 \times 6.5 = 2.717$  Allow 2.7 – 2.717 (1)

or =  $0.1 \times 4.2 \times 6.5 = 2.730$  (or 2730) if 4.2 used for 'c'

**Ignore units in part (c)**

2

(d) Molar enthalpy change =  $-2.717 / 5.00 \times 10^{-2}$  (1)

=  $-54.3$   $\text{kJ mol}^{-1}$  (1)

*Allow conseq to answers in (b) and (c)*

**Mark CE if this inverted**

2

[6]

9

- (a) standard enthalpy of formation (1)

allow enthalpy of formation under standard conditions

1 mol of a compound produced (1)

from elements under standard conditions (1)

reactants and products in standard states (1)

allow normal or most stable states under standard conditions

correct explanation not linked to correct name

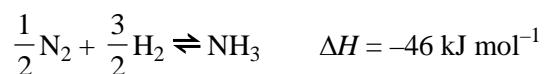
4

- (b) (i)  $\text{NO} + \frac{5}{2}\text{H}_2 \rightarrow \text{NH}_3 + \text{H}_2\text{O}$  or doubled (1)

allow two equations, single and doubled

mark on from wrong moles of  $\text{H}_2$  (for which  $\Delta H_f$  is zero)

- (ii)  $\text{NO} \rightleftharpoons \frac{1}{2}\text{N}_2 + \frac{1}{2}\text{O}_2 \quad \Delta H = -91 \text{ kJ mol}^{-1}$



correct equations or cycle (1)

$$\therefore \Delta H = -91 - 46 - 242 \text{ (1)} = -379 \text{ kJ mol}^{-1} \text{ (1)}$$

minus 1 for each wrong sign

if eqn in (i) and value in (ii) do not match, then MAX 2 ex 3

$$\Delta H = \sum \Delta H_{\text{prod}} - \sum \Delta H_{\text{react}} \text{ (shown) gets 1 if zero otherwise}$$

4

[8]

- 10
- (a) (Enthalpy change) when 1 mol (1) of a compound is formed from its constituent elements (1) in their standard states (1)  
**Allow energy or heat, ignore evolved or absorbed**  
**Mark each point independently**
- 3
- (b) (The enthalpy change for a reaction is) independent of the route (1)
- 1
- (c)  $\Delta H_R = \Sigma \Delta H_f \text{ products} - \Sigma \Delta H_f \text{ reactants}$  (1)  
 $= [(3 \times -286) + (3 \times -394)] - (-248)$  (1)  
 $= -1792$  (1) (kJ mol<sup>-1</sup>)  
**Deduct one mark for each error to zero**
- 3
- [7]

11

- (a) (Energy required) to break a given covalent bond (1)  
averaged over a range of compounds (1)  
**Penalise first mark if 'energy' / 'enthalpy' evolved**

2

- (b) (i)  $4 \times \text{C-H} = 4 \times 413 = +1652$   
 $1 \times \text{C-C} = 1 \times 347 = 347$   
 $1 \times \text{C=O} = 1 \times 736 = 736$   
 $2\frac{1}{2} \times \text{O=O} = 2.5 \times 498 = 1245$  (1)  
 $= 2735 + 1245 = +3980$  (1)  
**first mark for 4 : 1: 1 or 2735 ignore sign**

- (ii)  $4 \times \text{H-O} = -4 \times 464 = -1856$   
 $4 \times \text{C-O} = -4 \times 736 = -2944$  (1)  
 $= -4800$  (1)

**First mark for 4 : 4**

- (iii)  $\Delta H_R = \sum \text{Bonds broken} - \sum \text{Bonds made}$   
 $= +3980 - 4800 = -820$  (1)  
**Conseq Mark for incorrect answers in (i) and (ii) as**  
**(i) Answer + (ii) Answer =**

5

[7]



12

- (a) { heat { molecule  
 { enthalpy change for formation of 1 mol of a { substance (1)  
 { compound

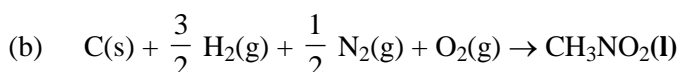
from its elements (1)

in their standard states \* (at 298 K, 100 kPa) (1)

(\*) or natural/normal states at 298 K, 100 kPa

*must have 2<sup>nd</sup> mark to score third*

3



equation (1)

*not*  $\times 2$

state symbols (1)

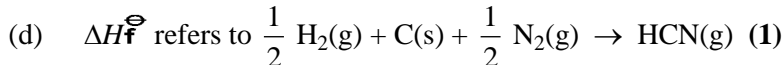
*can score for unbalanced equation or*  $\times 2$

2

- (c) Hess's law (1)

*or 1<sup>st</sup> Law or conservation of energy*

1



$$\Delta H^\ominus = \frac{1}{2} \Delta H_c^\ominus (\text{H}_2) + \Delta H_c^\ominus (\text{c}) + \frac{1}{2} \Delta H_c^\ominus (\text{N}_2) - \Delta H_c^\ominus (\text{HCN}) \quad (1)$$

$$= -121 \quad -394 \quad +34 \quad -(-611) \quad (1)$$

$$= +130 \text{ (kJmol}^{-1}\text{)} \quad (1)$$

(for wrong answers allow )

( -130 (2) )

( +260 (3) )

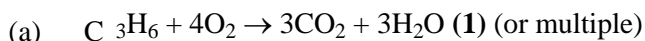
( -260 (1) )

4

[10]



13



1

(b) (i)  $\frac{1.45}{58}$  (1) = 0.0250 (1)

*allow 0.025**allow conseq on wrong  $M_r$* 

$1.45/100, \text{CE}; \frac{1.45}{58.1} \text{ C.E.}$

(ii) heat released =  $mc\Delta T$

$= 100 \times 4.18 \times 58.1$  (1)

*if 1.45 used in place of 100 CE = 0*

$= 24300 \text{ J}$  (1) (or 24.3kJ)

*allow 24200 to 24300**ignore decimal places**units tied to answer**If use  $0.1 \times 4.18 \times 51.8$  allow  $\frac{1}{2}$  for 24.3 with no units*

(iii)  $\frac{24.3}{0.0250} = -972 \text{ (kJ mol}^{-1}\text{)}$  (1)

5

*allow -968 to -973**allow +972**allow conseq**allow no units**penalise wrong units*

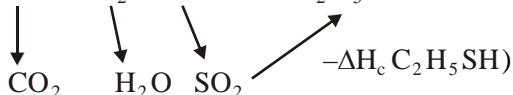
(c) (i) Heat loss (1) or energy loss

*do not allow incomplete combustion*

(ii) Difference: more negative (1) (or more exothermic)

*QoL mark**Explanation: heat (or energy) released when water vapour condenses* (1) 3*or heat/energy required to vaporise water**or water molecules have more energy in the gaseous state*

(d)  $\Delta H = \Sigma \Delta H_{\text{reactants}} - \Sigma \Delta H_{\text{products}}$  (1)

(or cycle  $2\text{C} + 3\text{H}_2 + \text{S} \rightarrow \text{C}_2\text{H}_5\text{SH}$ )

$= (2 \times -394) + (3 \times -286) + (-297) - (-1170)$  (1) = -773 (1)

3

*ignore units even if wrong**Allow  $\frac{1}{3}$  for +773*

[12]



14

- (a) Enthalpy (Energy) to break a (covalent) bond (1) **OR dissociation energy**  
Varies between compounds so average value used (1) **QL mark**  
**OR average of dissociation energies in a single molecule / e.g. CH<sub>4</sub>**  
**Do not allow mention of energy to form bonds**  
**but with this case can allow second mark otherwise 2<sup>nd</sup> mark**  
**consequential on first**

2

- (b) (i)  $\frac{1}{2} \text{N}_2 + \frac{3}{2} \text{H}_2 \rightarrow \text{NH}_3$  (1)  
**Ignore s s**

- (ii)  $\Delta H = (\Sigma)\text{bonds broken} - (\Sigma)\text{bonds formed}$  (1)  
 $= \frac{1}{2} \times 944 + \frac{3}{2} \times 436 - 3 \times 388$  (1)  
 $= -38 \text{ kJ mol}^{-1}$  (1)  
**Ignore no units, penalise wrong units**  
**Score 2/3 for -76**  
**1/3 for +38**  
**Allow 1/3 for +76**

4

- (c)  $4 (\text{C-H}) + (\text{C}=\text{C}) + (\text{H-H}) - (6 (\text{C-H}) + (\text{C-C})) = -136$  (1)  
 $(\text{C}=\text{C}) + (\text{H-H}) - ((\text{C-C}) + 2 (\text{C-H})) = -136$   
 $2 (\text{C-H}) = 836$  (1)  
 $(\text{C-H}) = 418 (\text{kJ mol}^{-1})$  (1)  
**Note: allow (1) for -836**  
**another (1) for -418**

3

[9]

15

- (a) (i) enthalpy (or heat or heat energy) change when

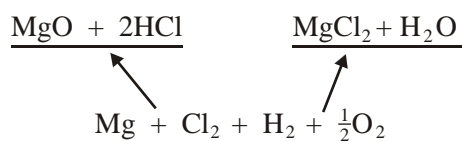
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1 mol of a substance (1) (QL mark) is formed from its elements (1)  
all substances in their standard states (1) (or normal states at 298K,  
 100 kPa or std condits)  
*not STP, NTP*

- (b) enthalpy change (or enthalpy of reaction) is independent of route (1)

$$\Delta H = \sum \Delta H_f^\ominus \text{ prods} - \sum \Delta H_f^\ominus \text{ reactants (or cycle) (1)}$$

minimum correct cycle is:



$$\Delta H = -642 - 286 - (-602 + 2 \times -92) \text{ (1)}$$

$$= -142 \text{ (kJ mol}^{-1}\text{) (1)}$$

*penalise this mark for wrong units*

*+142 scores 1 mark out of the last three*

4



(c)  $\Delta H = mcT$  (1) (or  $mc\Delta T$ )  
 $= 50 \times 4.2 \times 32 = 6720 \text{ J} = 6.72 \text{ J}$  (1)  
*mark is for 6720 J or 6.72 kJ*

moles HCl =  $\frac{\text{vol}}{1000} \times \text{conc} = \frac{50}{1000} \times 3$  (1)  
 $= 0.15$  (1)  
*if error here mark on conseq.*

Therefore moles of MgO reacted = moles HCl/2 (1) (mark is for/2, CE if not/2)  
 $= 0.15/2 = 0.075$

Therefore  $\Delta H = 6.72/0.075$  (1) 8  
 $= -90 \text{ kJ (mol}^{-1}\text{)}$   
*kJ must be given, allow 89 to 91*  
*value (1)*  
*sign (1); this mark can be given despite CE for /2*

Note various combinations of answers to part (c) score as follows:

$-89$  to  $-91 \text{ kJ}$  (8) (or  $-89000$  to  $91000\text{J}$ )  
*no units (7)*

$+89$  to  $+91 \text{ kJ}$  (7) (or  $+89000$  to  $+91000\text{J}$ )  
*no units (6)*

$-44$  to  $-46 \text{ kJ}$  (5) (or  $-44000$  to  $-46000\text{J}$ )  
*no units (4) if units after 6.72 or 6720 (5)*

$+44$  to  $+46 \text{ kJ}$  (4) (or  $+44000$  to  $+46000\text{J}$ )  
*if no units and*  
*if no units after 6.72 or 6720 (3)*  
*otherwise check, could be (4)*

[15]



- 16
- (a) (i) enthalpy change when 1 mol of a substance (or compound) (QL mark) 1  
is (completely) burned in oxygen (or reacted in excess oxygen) 1  
at 298 K and 100 kPa (or under standard conditions) 1
- (ii) heat produced = mass of water  $\times$  Sp heat capacity  $\times \Delta T$  (or  $mc\Delta T$ ) 1  
=  $150 \times 4.18 \times 64$  (note if mass = 2.12 lose first 2 marks then conseq) 1  
= 40100 J or = 40.1 kJ (allow 39.9-40.2 must have correct units) 1  
moles methanol = mass/ $M_r$  =  $2.12/32$  (1) 1  
= 0.0663
- $\Delta H = -40.1/0.0663 = -605 \text{ kJ (mol}^{-1}\text{)}$  1  
(allow -602 to -608 or answer in J)  
(note allow conseq marking after all mistakes but note use of  
2.12 g loses 2 marks)
- (b)  $\Delta H = \sum \Delta H_c^\ominus(\text{reactants}) - \sum \Delta H_c^\ominus(\text{products})$  (or correct cycle) 1
- $\Delta H_c^\ominus(\text{CH}_3\text{OH}) = \Delta H_c^\ominus(\text{CO}) + 2 \times \Delta H_c^\ominus(\text{H}_2) - \Delta H$  1  
=  $(-283) + (2 \times -286) - (-91)$  (mark for previous equation or this)  
=  $-764 \text{ (kJ mol}^{-1}\text{)}$  (units not essential but lose mark if units wrong) 1  
(note + 764 scores 1/3)

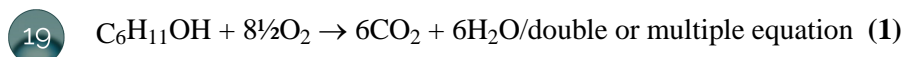
[10]

- 17
- (a) enthalpy (or energy) to break (or dissociate) a bond; 1  
 averaged over different molecules (environments); 1  
 enthalpy (or heat energy) change when one mole of a compound; 1  
 is formed from its elements; 1  
 in their standard states; 1
- (b) enthalpy change =  $\Sigma(\text{bonds broken}) - \Sigma(\text{bonds formed})$  or cycle; 1  
 $= 4 \times 388 + 163 + 2 \times 146 + 4 \times 463 - (944 + 8 \times 463)$ ; 1  
 (or similar) 1  
 $= -789$ ; 1  
 (+ 789 scores 1 only)
- (c) (i) zero; 1  
 (ii)  $\Delta H = \Sigma(\text{enthalpies of formation of products})$   
 $-\Sigma(\text{enthalpies of formation of reactants})$  1  
 $= 4 \times -242 - (75 + 2 \times -133)$ ; 1  
 $= -777$ ; 1  
 (+ 777 scores one only)
- (d) mean bond enthalpies are not exact 1  
 (or indication that actual values are different from real values)

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- (b)  $\text{Li(s)} + \frac{1}{2} \text{O}_2(\text{g}) + \frac{1}{2} \text{H}_2(\text{g}) \rightarrow \text{LiOH(s)}$  equation (1)  
 ss (1) 2
- (c)  $\text{Li(s)} + \text{H}_2\text{O(l)} \rightarrow \text{Li}^+(\text{aq}) + \text{OH}^-(\text{aq}) + \frac{1}{2} \text{H}_2(\text{g})$  equation (1)  
 ss (1) 2
- (d)  $\Delta H = \Delta H_f^\ominus(\text{LiOH(aq)}) - \Delta H_f^\ominus(\text{H}_2\text{O(l)})$  or cycle (1)  
 $= -487 - 21 - (-286)$  (1)  
 $= -222 \text{ (kJ mol}^{-1}\text{)}$  (1)  
 (allow (1) for -201)  
 reactivity increases (1)  
 Relationship between  $\Delta H^\ominus$  and reactivity none (1)  
 Reason reactivity governed by rate (or  $E_a$ ) (1) 3

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[1]

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$$\begin{aligned}\text{moles methane} &= \frac{0.10}{16} = 6.25 \times 10^{-3} \text{ (1)} \\ \text{kJ evolved} &= 6.25 \times 10^{-3} \times 890 = 5.56 \text{ (1)} \\ 5.56 \times 10^3 \text{ joules} &= (mc)\Delta T \text{ (1)} \\ \Delta T &= \frac{5.56 \times 10^3}{120} = 46.4 \text{ K (1)}\end{aligned}$$

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[4]