

## **A-Level Chemistry**

Gibb's Free Energy

**Mark Scheme** 

Time available: 69 minutes Marks available: 61 marks

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## Mark schemes

- 1.
- (a) CO<sub>2</sub> / gas is more disordered (than solid)

Allow answers based on carbon Ignore CO<sub>2</sub> is a gas and C is a solid

1

(b) 0 K

Units essential

Allow absolute zero OR -273 °C

1

(c) M1  $\Delta H = (3^x - 394) - (-1669 \times 2)$ M1 correct expression

1

 $M2 = 2156 \text{ (kJ mol}^{-1}\text{)}$ 

M2 if -2156 seen allow 1 mark out M1 and M2

1

M3  $\Delta S = (28 \times 4 + 214 \times 3) - (51 \times 2 + 6 \times 3)$ 

M3 correct expression

1

 $M4 = 634 (J K^{-1} mol^{-1})$ 

M4 if - 634 allow 1 mark from M4 and M4

1

M5  $\Delta G = \Delta H - T \Delta S$  or  $\Delta H = T \Delta S$  or  $T = \Delta H \neq \Delta S$ 

M5 expression or rearranged expression or with numbers

1

M6  $\Delta S = 0.634 \text{ kJ K}^{-1} \text{mol}^{-1}$ 

 $M6 \Delta S = M4 \div 1000$ 

1

1

M7  $T = \frac{2156}{0.634} = 3400 \text{ to } 3401 \text{ (K)}$ 

 $M7 = M2 \div M6$  but must be a positive answer

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1

**M2** 
$$\Delta H = -49 \text{ (kJ mol}^{-1}\text{)}$$

Allow consequential marking

**M2** 1 mark for  $\Delta H = +49 \ (kJ \ mol^{-1})$ 

1

**M3** 
$$\Delta S = -180 \text{ (J K}^{-1} \text{ mol}^{-1}\text{)}$$

1

**M4** 
$$\Delta G = \Delta H - T\Delta S$$

M4 Recall this equation. If M4 incorrect cannot score M6

1

**M5** 
$$\Delta G = -49 - \frac{890 \text{ x} - \frac{180}{1000}}{1000}$$
 or **M3**÷1000

**M5** Conversion of  $\Delta$ S into kJ mol<sup>-1</sup>

$$\Delta G = M2 - \frac{(890 \text{ x M3})}{1000}$$

1

**M6** 
$$\Delta G = 111 \text{ (kJ mol}^{-1}\text{)}$$

If  $\Delta S$  not converted to kJ in **M5**, answer is +160151 kJ mol<sup>-1</sup> = 5 marks

1

(b) M1  $\Delta H = \text{intercept of y axis} = 145 \text{ (kJ mol}^{-1}\text{)}$ 

M1 Value between 144 and 146 kJ mol-1

1

**M2** Gradient =  $-\Delta S$  or a negative value

1

M3 Gradient x 1000

1

**M4** 
$$\Delta S = +167 \text{ to } +173 \text{ (J K}^{-1} \text{ mol}^{-1}\text{)}$$

**M4** +0.167 to +0.173 scores 2 for  $\Delta$ S

-167 to -173 scores 2 for  $\Delta S$ 

-0.167 to -0.173 scores 1 for  $\Delta$ S

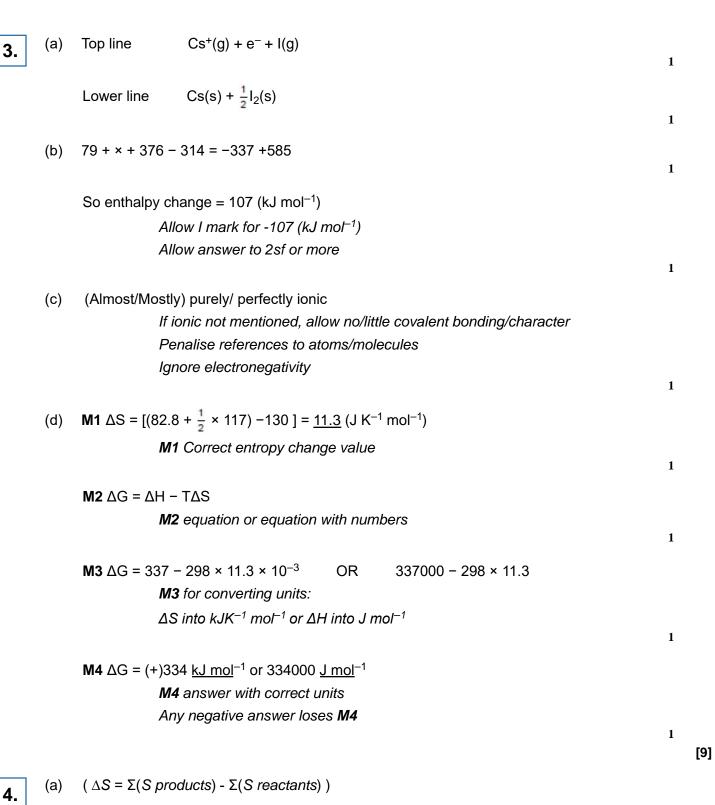
1

1

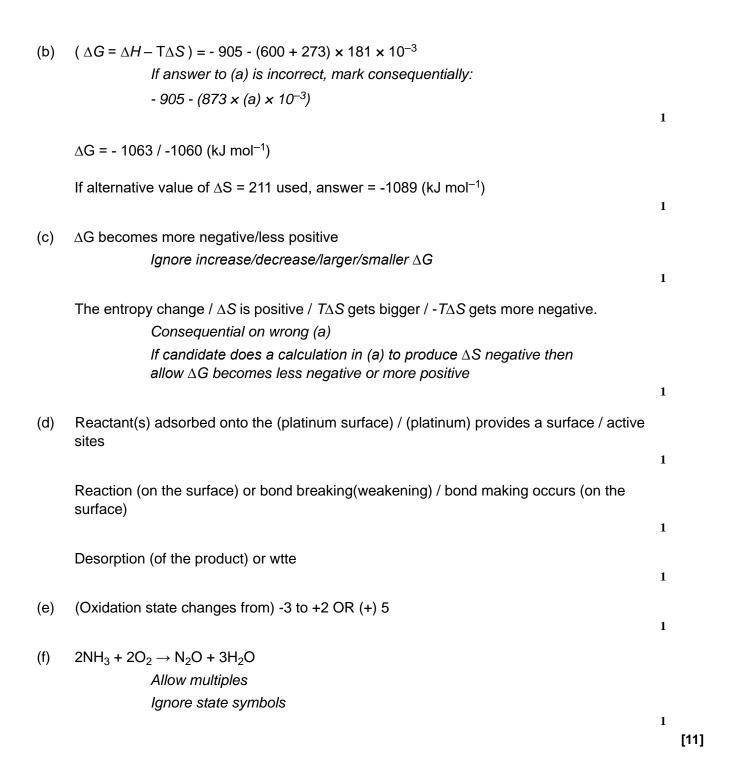
(c) <u>Above</u> 845 K reaction becomes (thermodynamically) feasible OR <u>Below</u> 845 K reaction is not (thermodynamically) feasible

Allow 845 to 860

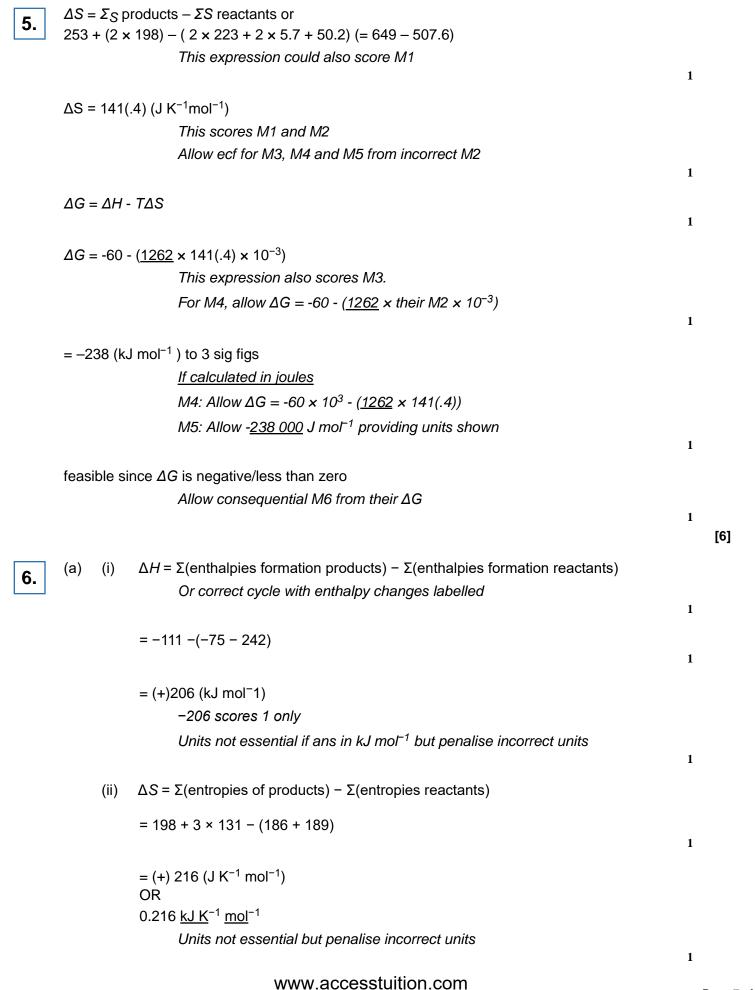
[11]



 $= [ (4 \times 211) + (6 \times 189) ] - [ (4 \times 193) + (5 \times 205) ] = (1978 - 1797)$  1  $181 (J K^{-1} mol^{-1})$ 



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(b) When  $\Delta G = 0$  OR  $\Delta H = T\Delta S$ 1  $T = \Delta H / \Delta S$ M2 also scores M1 1  $= 206 \times 1000 / 216$ Allow error carried forward from (a)(i) and (a)(ii) Ignore unexplained change of sign from - to + 1 = 954 KAllow 953 - 955. Units of K essential, must be +ve If values from (a)(i) and (a)(ii) lead to negative value in M3 allow M1 to M3 but do not allow negative temperature for M4 If negative value changed to positive for M4, allow M4 1 To speed up the rate of reaction OR wtte (c) Allow so that more molecules have energy greater than the activation energy IF T in (b) > 1300 allow answers such as; to reduce energy cost to slow down reaction do NOT allow to increase rate 1 (d) Method 1 (i)  $\Delta G = \Delta H - T \Delta S$  $\Delta G = -41 - (1300 \times -42 / 1000) (M1)$ If 42 and not 42 / 1000 used can score M3 only but allow  $\Delta G = -41 \times 1000 - (1300 \times -42)$  (M1) 1  $= +13.6 \text{ kJ mol}^{-1}$  $=13600 \ <u>J \ mol^{-1} \ (M2)$ </u> Units essential 1  $\Delta G$  must be negative for the reaction to be feasible. OR  $\Delta G$  is positive so reaction is not feasible 1

## Method 2

For reaction to be feasible  $\Delta G$  must be negative or zero 1 T when  $\Delta G = 0 = \Delta H / \Delta S = 976K$ 1  $\Delta S$  is -ve so  $\Delta G$  must be +ve at temperatures above 976K / at 1300 K 1 (ii) If the temperature is lowered (Ignore reference to catalyst and / or pressure) Alternative mark scheme (if T is calculated) Allow T reduced to 976 K or lower M1 1  $\Delta G$  will become (more) negative because the  $-T\Delta S$  term will be less positive /  $T\Delta S > \Delta H$ At this temperature (the reaction becomes feasible because)  $\Delta G$  < = 0 M2

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1

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