A-Level Chemistry

Gibb's Free Energy

Mark Scheme

Time available: 69 minutes
Marks available: 61 marks

1.

(a) CO_2 / gas is more disordered (than solid)

Allow answers based on carbon

Ignore CO_2 is a gas and C is a solid

1

(b) 0 K

Units essential

*Allow absolute zero **OR** –273 ^oC*

1

(c) M1 ΔH = (**3**x – 394) –(–1669 x **2**)

M1 correct expression

1

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

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

1

M3 ΔS = (28 x **4** + 214 x **3**) – (51 x **2** + 6 x **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 $T = \Delta H \div \Delta S$

M5 expression or rearranged expression or with numbers

1

M6 ΔS = 0.634 kJ $K^{-1}$$mol^{-1}$

M6 ΔS = M4 ÷ 1000

1

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

M7 = M2 ÷ M6 but must be a positive answer

1

[9]

2. (a) **M1** $\Delta H = (-201 + -242) - (-394)$

1

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

Allow consequential marking

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

1

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

1

M4 $\underline{\Delta G = \Delta H - T\Delta S}$

M4** Recall this equation. If **M4** incorrect cannot score **M6

1

M5 $\Delta G = -49 - \left[\frac{890 \times -180}{1000}\right]$ or **M3**÷1000

***M5** Conversion of ΔS into kJ mol^{-1}*

$\Delta G =$ ***M2*** $- \frac{(890 \times M3)}{1000}$

1

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

*If ΔS not converted to kJ in **M5**, answer is +160151 kJ mol^{-1} = 5 marks*

1

(b) **M1** ΔH = intercept of y axis = 145 (kJ mol^{-1})

***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 ΔS = +167 to +173 (J K^{-1} mol^{-1})

***M4** +0.167 to +0.173 scores 2 for ΔS*

−167 to −173 scores 2 for ΔS

−0.167 to −0.173 scores 1 for ΔS

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

1

[11]

3. (a) Top line $Cs^+(g) + e^- + I(g)$

1

Lower line $Cs(s) + \frac{1}{2}I_2(s)$

1

(b) $79 + \times + 376 - 314 = -337 + 585$

1

So enthalpy change = 107 (kJ mol^{-1})

Allow I mark for -107 (kJ mol^{-1})

Allow answer to 2sf or more

1

(c) (Almost/Mostly) purely/ perfectly ionic

If ionic not mentioned, allow no/little covalent bonding/character

Penalise references to atoms/molecules

Ignore electronegativity

1

(d) **M1** $\Delta S = [(82.8 + \frac{1}{2} \times 117) - 130] = \underline{11.3}$ (J K^{-1} mol^{-1})

***M1** Correct entropy change value*

1

M2 $\Delta G = \Delta H - T\Delta S$

***M2** equation or equation with numbers*

1

M3 $\Delta G = 337 - 298 \times 11.3 \times 10^{-3}$ OR $337000 - 298 \times 11.3$

***M3** for converting units:*

ΔS into kJK^{-1} mol^{-1} or ΔH into J mol^{-1}

1

M4 ΔG = (+)334 $\underline{kJ\ mol^{-1}}$ or 334000 $\underline{J\ mol^{-1}}$

***M4** answer with correct units*

*Any negative answer loses **M4***

1

[9]

4. (a) ($\Delta S = \Sigma(S\ products) - \Sigma(S\ reactants)$)

$= [(4 \times 211) + (6 \times 189)] - [(4 \times 193) + (5 \times 205)] = (1978 - 1797)$

1

181 (J K^{-1} mol^{-1})

1

(b) ($\Delta G = \Delta H - T\Delta S$) = - 905 - (600 + 273) × 181 × 10^{-3}

If answer to (a) is incorrect, mark consequentially:

- 905 - (873 × (a) × 10^{-3})

1

ΔG = - 1063 / -1060 (kJ mol^{-1})

If alternative value of ΔS = 211 used, answer = -1089 (kJ mol^{-1})

1

(c) ΔG becomes more negative/less positive

Ignore increase/decrease/larger/smaller ΔG

1

The entropy change / ΔS is positive / $T\Delta S$ gets bigger / $-T\Delta S$ gets more negative.

Consequential on wrong (a)

If candidate does a calculation in (a) to produce ΔS negative then allow ΔG becomes less negative or more positive

1

(d) Reactant(s) adsorbed onto the (platinum surface) / (platinum) provides a surface / active sites

1

Reaction (on the surface) or bond breaking(weakening) / bond making occurs (on the surface)

1

Desorption (of the product) or wtte

1

(e) (Oxidation state changes from) -3 to +2 OR (+) 5

1

(f) $2NH_3 + 2O_2 \rightarrow N_2O + 3H_2O$

Allow multiples

Ignore state symbols

1

[11]

5. $\Delta S = \Sigma_S$ products – ΣS reactants or
253 + (2 × 198) – (2 × 223 + 2 × 5.7 + 50.2) (= 649 – 507.6)

This expression could also score M1

1

ΔS = 141(.4) (J $K^{-1}mol^{-1}$)

This scores M1 and M2

Allow ecf for M3, M4 and M5 from incorrect M2

1

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

1

ΔG = -60 - (1262 × 141(.4) × 10^{-3})

This expression also scores M3.

For M4, allow ΔG = -60 - (1262 × their M2 × 10^{-3})

1

= –238 (kJ mol^{-1}) to 3 sig figs

If calculated in joules

M4: Allow ΔG = -60 × 10^3 - (1262 × 141(.4))

M5: Allow -238 000 J mol^{-1} providing units shown

1

feasible since ΔG is negative/less than zero

Allow consequential M6 from their ΔG

1

[6]

6. (a) (i) ΔH = Σ(enthalpies formation products) − Σ(enthalpies formation reactants)

Or correct cycle with enthalpy changes labelled

1

= −111 −(−75 − 242)

1

= (+)206 (kJ mol⁻1)

−206 scores 1 only

Units not essential if ans in kJ mol^{-1} but penalise incorrect units

1

(ii) ΔS = Σ(entropies of products) − Σ(entropies reactants)

= 198 + 3 × 131 − (186 + 189)

1

= (+) 216 (J K^{-1} mol^{-1})
OR
0.216 kJ K^{-1} mol^{-1}

Units not essential but penalise incorrect units

1

(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 K

Allow 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

(c) To speed up the rate of reaction OR wtte

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) (i) **Method 1**

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

$\Delta G = -41 - (1300 \times -42 / 1000)$ (M1)

If 42 and not 42 / 1000 used can score M3 only

but allow $\Delta G = -41 \times 1000 - (1300 \times -42)$ (M1)

1

$= +13.6$ kJ mol^{-1}

$= 13600$ J mol^{-1} (M2)

Units essential

1

ΔG must be negative for the reaction to be feasible.

OR ΔG is positive so reaction is not feasible

1

Method 2

For reaction to be feasible Δ*G* must be negative or zero

1

T when Δ*G* = 0 = Δ*H* / Δ*S* = 976*K*

1

Δ*S* is −ve so Δ*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

Δ*G* will become (more) <u>negative</u> because

<u>the −*T*Δ*S* term will be less positive / *T*Δ*S*>Δ*H*</u>

At this temperature (the reaction becomes feasible because) ΔG < = 0 M2

1

[15]