InkChemistry

ANSWER BOOK

Entropy and Gibbs free-energy change

Thermodynamics · Unit C08

AQA 3.1.8.2 · OCR A 5.2.2

18 questions · 51 marks

NAVY EDITION

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SECTION A · Short, 1 to 2 marks

A1 EG-Q1

B1 entropy is a measure of disorder, the number of ways the particles and their energy can be arranged. **B1** its units are J K^{-1} mol^{-1}. [2]

A2 EG-Q3

B1 reaction B has the largest positive entropy change. **B1** a solid produces a mole of gas, whereas A has no change in the moles of gas and C has fewer moles of gas in the products. [2]

A3 EG-Q11

B1 the gradient of the line is -ΔS. **B1** when the reactant boils its entropy jumps, so ΔS for the reaction changes and so does the gradient. [2]

A4 EG-Q14

B1 ΔH and ΔS both change with temperature, but the calculation assumes they stay at their 298 K values. **B1** a substance in the reaction may melt or boil between 298 K and 1500 K, changing its entropy and so ΔS. [2]

A5 EG-Q2

B1 a reaction is feasible when ΔG is zero or negative. [1]

SECTION B · Standard, 3 to 5 marks

B1 EG-Q12

B1 ΔH is positive, so on its own it makes ΔG positive. **B1** a solid produces a gas, so ΔS is positive and the term -TΔS is negative. **B1** at room temperature TΔS is smaller than ΔH, so ΔG is positive and the reaction is not feasible. **B1** as T rises, TΔS grows until it exceeds ΔH, so above T = ΔH/ΔS the value of ΔG is negative and the reaction is feasible. [4]

B2 EG-Q16

B1 a positive ΔG means the equilibrium lies on the side of the reactants, not that no ammonia forms; some ammonia is present at equilibrium. **B1** high pressure moves the equilibrium position towards ammonia, and ammonia is removed as it forms, so a useful yield is obtained at 700 K. **B1** at room temperature the reaction is feasible but its activation energy is so high that it is far too slow, even with an iron catalyst. **B1** the claim is therefore wrong: the operating temperature is a compromise between a feasible, high-yield temperature and a fast rate. [4]

B3 EG-Q18

M1 ΔH is converted to joules: +117 kJ mol^{-1} = +117000 J mol^{-1}. **M1** ΔS(surroundings) = -ΔH ÷ T = -117000 ÷ 298. **A1** ΔS(surroundings) = -393 J K^{-1} mol^{-1}, three significant figures, negative sign required. **A1** ΔS(total) = +175 + (-393) = -218 J K^{-1} mol^{-1}, error carried forward from the previous mark; negative, so the decomposition does not take place at 298 K. [4]

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B4 EG-Q5 — **M1** ΔS is converted to kJ: -327 ÷ 1000 = -0.327 kJ K^{-1} mol^{-1}. **M1** ΔG = -572 - (298 × -0.327) = -572 + 97.4. **A1** ΔG = -475 kJ mol^{-1}, three significant figures, negative sign required; an answer near +96 900, from ΔS left in joules, is not credited. [3]

B5 EG-Q9 — **B1** on melting the particles leave fixed positions but stay in contact, so the disorder increases a little. **B1** on boiling the particles separate completely and move freely through a much larger volume. **B1** the number of ways of arranging the particles and their energy rises far more on boiling, so the entropy jump is much larger. [3]

B6 EG-Q10 — **B1** a negative ΔG shows that the change is feasible, but says nothing about its rate. **B1** the change has a very high activation energy, because strong covalent bonds must be broken. **B1** at room temperature almost no particles have enough energy to react, so the rate is too slow to observe and diamond is kinetically stable. [3]

B7 EG-Q13 — **B1** the decomposition forms two moles of gas from a solid, so ΔS is large and positive, and ΔH is positive. **B1** at the hot bottom of the tube TΔS exceeds ΔH, so ΔG is negative and the decomposition is feasible. **B1** at the cooler top TΔS is smaller than ΔH, so ΔG for the decomposition is positive and the reverse reaction, forming solid NH_4Cl, is feasible instead. [3]

B8 EG-Q15 — **B1** the reaction with negative ΔH and negative ΔS is feasible only below the temperature T = ΔH/ΔS. **B1** the reaction with positive ΔH and positive ΔS is feasible only above the temperature T = ΔH/ΔS. **B1** in both, the TΔS term grows with temperature: in the first it works against feasibility and in the second it makes the reaction feasible. [3]

B9 EG-Q17 — **B1** the entropy starts at zero at 0 K and rises gradually through the solid as the particles vibrate more. **B1** it rises vertically at 273 K as the ice melts, then rises gradually again through the liquid. **B1** it rises vertically by a much larger amount at 373 K as the water boils, then rises gradually through the gas. [3]

B10 EG-Q19 — **B1** the heat released by the reaction passes into the surroundings and is spread among their particles. **B1** this increases the number of ways the energy of the surroundings can be arranged, so ΔS(surroundings) = -ΔH/T is positive when ΔH is negative. **B1** a given quantity of heat makes a larger difference to cold surroundings, which hold less energy to begin with, so the increase is larger at low T, as the division by T shows. [3]

B11 EG-Q20 — **M1** ln K = -ΔG ÷ RT, with ΔG converted to -4700 J mol^{-1}. **M1** ln K = 4700 ÷ (8.31 × 298) = 1.90. **A1** K = exp(1.90) = 6.7, two significant figures, with no units. [3]

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B12 EG-Q21

B1 ln K = −ΔG ÷ RT = −5000 ÷ (8.31 × 298) = −2.0. **B1** K = exp(−2.0) = 0.13, less than 1 but far from zero. **B1** the equilibrium lies towards the reactants but contains products in appreciable amounts: a positive ΔG means the reaction does not go to completion, not that no product forms. [3]

B13 EG-Q23

M1 the reaction becomes feasible when ΔG = ΔH − TΔS falls to zero, so T = ΔH ÷ ΔS. **M1** the units must match: ΔH = 178 000 J mol^{-1}, so T = 178 000 ÷ 161. **A1** T = 1106 K, about 1110 K; above this temperature TΔS exceeds ΔH, ΔG is negative and the decomposition is feasible. [3]

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