

## MARKSCHEME - HL THERMODYNAMICS

P1A: 1.B, 2.C (Be<sup>2+</sup> high charge density), 3.A (DG=100-500\*0.2=0 at 500K), 4.B, 5.D, 6.C, 7.C, 8.C, 9.B, 10.B, 21.A, 30.A

P1B Q1: (a) (i) Mg(g) + 1/2 O<sub>2</sub>(g) [1], (ii) Mg<sup>+</sup>(g) + 1/2 O<sub>2</sub>(g) + e<sup>-</sup> [1], (iii) Mg<sup>2+</sup>(g) + O<sub>2</sub><sup>-</sup>(g) [1]. (b) MgO(s) → Mg<sup>2+</sup>(g) + O<sub>2</sub><sup>-</sup>(g) [1]. (c) Lattice enthalpy is extremely exothermic due to high charges/small radii [1], which outweighs all endothermic steps [1].

P1B Q2: (a) Cycle showing KCl(s) to gaseous ions then hydrated ions [1]. (b) DH<sub>sol</sub> = 711 + (-322 - 364) = +25 kJ mol<sup>-1</sup> [2]. (c) Increase in entropy (+DS) [1]. DG = DH-TDS becomes negative at high T if DS is positive [1].

P1B Q3: (a) DS = DH/T = 40700 / 373 = 109.1 J K<sup>-1</sup> mol<sup>-1</sup> [2]. (b) Positive [1]. T < boiling point, DH > TDS [1].

P1B Q4: (a) B [1]. Better insulation reduces error from heat loss to surroundings [1]. (b) Recording temperature over time after reaction [1], plotting graph and extending cooling curve back to time of mixing to find true maximum T [1].

P2 Q1: DH<sub>f</sub> = 178 + 590 + 1145 + 2\*121 + 2\*-349 - 2258 = -792 kJ mol<sup>-1</sup> [5].

P2 Q2: Covalent character [1]. Al<sup>3+</sup> has high charge density and polarizes Br<sup>-</sup> [1].

P2 Q3: DS = 2(193) - (192 + 3\*131) = -199 J K<sup>-1</sup> mol<sup>-1</sup> [3].

P2 Q4: DG = -92 - (298 \* -0.199) = -32.7 kJ mol<sup>-1</sup> [2].

P2 Q5: T = -92 / -0.199 = 462 K. Non-spontaneous above 462 K [2].

P2 Q6: DG = -RT ln K → -10000 = -8.31 \* 500 \* ln K → ln K = 2.41 → K = 11.1 [2].

P2 Q7: Straight line upwards from positive y-intercept (DH) crossing T-axis [3].

P2 Q8: Mg<sup>2+</sup> higher Hydration Enthalpy [1]. Smaller ionic radius results in stronger attraction to water dipoles [1].

P2 Q9: Always Spont [1], Never Spont [1], Spont at Low T [1], Spont at High T [1].

P2 Q10: MgO [1]. Higher charges (2+/2-) result in 4x stronger attraction [1].