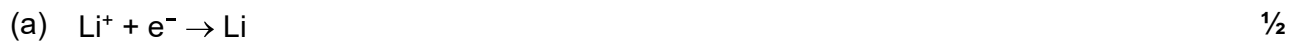


2. This question is about making ammonia



Multiples allowed. Equation must be fully correct to score the 1/2 mark.

(b) (i) $= (2 \times -268 \text{ kJ mol}^{-1}) + 15.8 \text{ kJ mol}^{-1} + (4 \times 15.0 \text{ kJ mol}^{-1}) - (4 \times -446 \text{ kJ mol}^{-1})$
 $= +1,320 \text{ kJ mol}^{-1}$ 1

Do not penalise if positive sign is absent, however, zero marks if negative.

(ii) $= (4 \times 63.7 \text{ J K}^{-1} \text{ mol}^{-1}) + (2 \times 224 \text{ J K}^{-1} \text{ mol}^{-1}) + 236 \text{ J K}^{-1} \text{ mol}^{-1} - (4 \times 128 \text{ J K}^{-1} \text{ mol}^{-1})$
 $= +427 \text{ J K}^{-1} \text{ mol}^{-1}$ 1

Do not penalise if positive sign is absent, however, zero marks if negative.

(iii) $= \Delta H^\ominus - T\Delta S^\ominus$
 $= 1,320 \text{ kJ mol}^{-1} - (750 \text{ K} \times 427 \text{ J K}^{-1} \text{ mol}^{-1} \times 10^{-3} \text{ kJ J}^{-1})$
 $= +1,004 \text{ kJ mol}^{-1}$

Do not penalise if positive sign is absent, however, zero marks if negative. ECF allowed from part (b)(i) and (b)(ii): 1

ECF Answer = (b)(i) - (0.75 × (b)(ii))

(c) $= \Delta G^\ominus / (n \times F)$
 $= -1,004 \text{ kJ mol}^{-1} \times 10^3 \text{ J kJ}^{-1} / (4 \times 9.65 \times 10^4 \text{ C mol}^{-1}) = -2.60 \text{ V}$ 1/2

ECF Answer = -((b)(iii) × 2.59 × 10⁻³)

Therefore, a potential of **+3.20 V** should be applied. 1/2

ECF Answer = ((b)(iii) × 2.59 × 10⁻³) + 0.60

1/2 mark for correct calculation of -2.60 V (negative sign required) and 1/2 mark for adding 0.60 V to the absolute value of E^o_{cell} students have obtained.

- (d) $6\text{Li} + \text{N}_2 \rightarrow 2\text{Li}_3\text{N}$ 1/2
 $\text{Li}_3\text{N} + 3\text{H}_2\text{O} \rightarrow \text{NH}_3 + 3\text{LiOH}$ 1/2
 Ratio Li:NH₃ is 3:1 1
1/2 mark for each correct equation. 1 mark for the correct ratio.
No ECF from incorrect equations.
- (e) $Q = 0.2 \text{ A} \times 1000 \text{ s} = 200 \text{ C}$
 Amount of e⁻ = $200 \text{ C} / 9.65 \times 10^4 \text{ C mol}^{-1} = 0.00207 \text{ mol}$ 1
 Amount of Li = $88.5\% \times 0.00207 \text{ mol} = 0.00183 \text{ mol}$ 1/2
 Mass of Li = $0.00183 \times 6.94 \text{ g mol}^{-1} = 0.0127 \text{ g}$ 1/2
1 mark for correct calculation of charge and correct use of Faraday's constant, 1/2 mark for calculation of amount of lithium from amount of electrons and 1/2 mark for correct numerical answer.
- (f) Amount of NH₃ = amount of Li $\times 1/3 = 0.00183 \text{ mol} \times 1/3 = 6.11 \times 10^{-4} \text{ mol}$ 1/2
 Volume of NH₃ = $6.11 \times 10^{-4} \text{ mol} \times 24000 \text{ cm}^3 \text{ mol}^{-1} = 14.7 \text{ cm}^3$ 1/2
ECF Answer = $3458 \times (\text{e}) / (\text{d})$
ECF Answer scores 1 mark.
- (g) Mass of NH₃ required for UK farm = $130 \text{ acres} \times 0.077 \text{ tonnes acre}^{-1} = 10.01 \text{ tonnes}$ 1/2
 Amount of NH₃ = $10.01 \times 10^6 \text{ g} / 17.034 \text{ g mol}^{-1} = 5.88 \times 10^5 \text{ mol}$ 1/2
 Amount of Li = $5.88 \times 10^5 \text{ mol} \times 3 = 1.76 \times 10^6 \text{ mol}$ 1/2
 Mass of Li = $1.76 \times 10^6 \text{ mol} \times 6.94 \text{ g mol}^{-1} = 1.22 \times 10^7 \text{ g} = 12.2 \text{ tonnes}$ 1/2
ECF Answer = $4.08 \times 10^6 \times (\text{d})$

Question Total 12