M1. (a) *M1* $K_p = (_pY)^3 \cdot (_pZ)^2 / (_pW)^2 \cdot (_pX)$ *NB [ ] wrong*

1

M2 temperature

1

M3 increase

1

M4 particles have more energy or greater velocity/speed

1

M5 more collisions with $E > E_a$ or more successful collisions

1

M6 Reaction exothermic or converse

1

M7 Equilibrium moves in the left

1

Marks for other answers
Increase in pressure or concentration allow M1, M5, M6 *Max 3*
Addition of a catalyst; allow M1, M5, M6 *Max 3*
Decrease in temperature; allow M1, M2, M6 *Max 3*
Two or more changes made; allow M1, M6 *Max 2*

(b) (i) Advantage; reaction goes to completion, not reversible
or faster

1

Disadvantage; reaction vigorous/dangerous
(exothermic must be qualified)

or HCl(g) evolved/toxic
or CH_3COCl expensive
NB Allow converse answers
Do not allow reactions with other reagents e.g. water
or ease of separation

1

(ii) $\Delta S = \Sigma S$ products $- \Sigma S$ reactants

1

$\Delta S = (259 + 187) - (201 + 161)$

1

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ΔS = 84 (JK^{-1} mol^{-1})   *(Ignore units)*

Allow – 84 to score (1) mark

1

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

1

$= -21.6 - 298 \times 84/1000$
$= -46.6$ kJ mol^{-1} or $-46\,600$ J mol^{-1}

1

Allow (2) for – 46.6 without units
(Mark ΔG consequentially to incorrect ΔS)
(e.g. ΔS = –84 gives ΔG = +3.4 kJ mol^{-1})

1

[15]

M2.B

[1]

M3.   (a)   (i)

$Ba^{2+}(g) + 2e^{(-)} + 2Cl(g)$

BE of Cl_2 or $2\Delta Ha$ Chlorine **(1)**

$2 \times EA$(chlorine) **(1)**
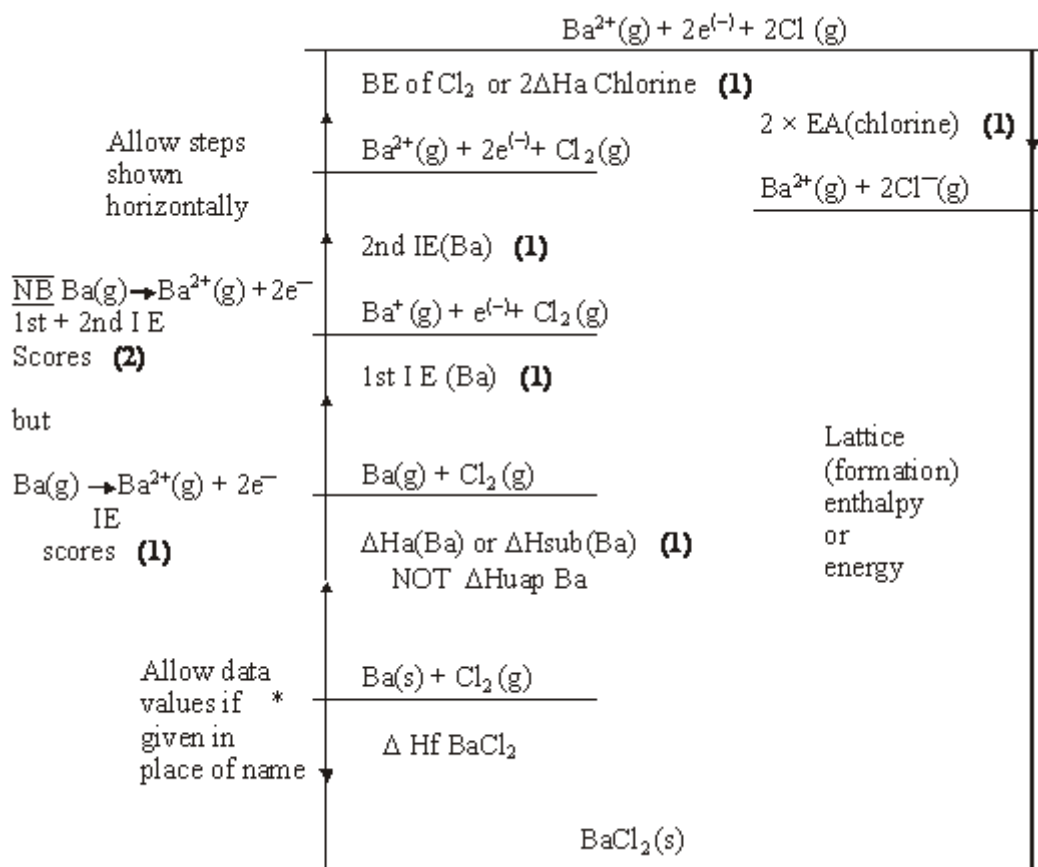
Allow steps shown horizontally

$Ba^{2+}(g) + 2e^{(-)} + Cl_2(g)$

$Ba^{2+}(g) + 2Cl^-(g)$

$\overline{NB}$ $Ba(g) \rightarrow Ba^{2+}(g) + 2e^-$
1st + 2nd I E
Scores **(2)**

2nd IE(Ba) **(1)**

$Ba^+(g) + e^{(-)} + Cl_2(g)$

1st I E (Ba) **(1)**

but

$Ba(g) \rightarrow Ba^{2+}(g) + 2e^-$
IE
scores **(1)**

$Ba(g) + Cl_2(g)$

Lattice (formation) enthalpy or energy

$\Delta Ha(Ba)$ or $\Delta Hsub(Ba)$ **(1)**
NOT $\Delta Huap$ Ba

Allow data values if *
given in place of name

$Ba(s) + Cl_2(g)$

Δ Hf $BaCl_2$

$BaCl_2(s)$

ONLY consider species involved in the step marked

(ii)   Cycling clockwise about (*)
        CE if step missing

$\Delta H_a Ba + 1^{st}$ IEBa + 2nd IE Ba + $2\Delta H_a Cl + 2EACl + LE - \Delta H_f BaCl_2 = 0$ **(1)**
+180 + 503 + 965 + 2 × 122 + 2EA −2056 + 859 = 0 **(1)**
EA = −695/2 = − (347 to 348) **(1)**

Ignore units

Calculation −1 for each error

Mark conseq.

Notes: −695 scores **(2)**
        +(347 to 348) scores **(2)**
        −(286 to 287) scores **(2)**
        +(286 to 287) scores **(1)**
        −573 scores **(1)**
        +573 scores **(0)**

9

(b)   ΔS = ΣS products – ΣS reactants
        = (63 +223) – 124 = 162 **(1)**

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$\Delta G = \Delta H - T\Delta S$ or $\Delta H = T\Delta S$ or $T = \Delta H/\Delta S$ **(1)**
      or used correctly

 $\Delta H = 859 \times 10^3$ **(1)** $= T \times 162$
 $T = (5\ 300\ \text{to}\ 5304)$ K **(1)**
      Penalise if units °C
      −1 for each error + mark conseq.

4

[13]

M4.A

[1]

M5.   (a)   (i)   *Standard enthalpy change*:
               $\Delta H_R = \Sigma\Delta H_f(\text{products}) - \Sigma\Delta H_f(\text{reactants})$ **(1)**
                 or cycle

               $\Delta H_R = ([2 \times 0] + [3 \times -393.5]) - (-824.2 + [3 \times -110.5])$ **(1)**
               $= -24.8$ (kJ mol^{-1}) **(1)**
                    Allow + 24.8 max one

               Standard entropy change: $\Delta S = \Sigma S(\text{products}) - \Sigma S(\text{reactants})$ **(1)**

               $\Delta S = ([2 \times 27.3] + [3 \times 213.6]) - (87.4 + [3 \times 197.6])$ **(1)**
                  $= (54.6 + 640.8) - (87.4 + 592.8)$ **(1)**
                  $= 15.2$ (JK^{-1}mol^{-1}) **(1)**
                    Allow -15.2 max one

            (ii) $\Delta G = \Delta H - T\Delta S$ **(1)**
               ΔH negative and $-T\Delta S$ is negative **(or ΔS positive or**
               or correct calc) (1)
               Hence ΔG is always negative
               (or feasible when ΔG $\leq$ 0) (1)

9

      (b) $\Delta G = O = \Delta H - T\Delta S$ Hence $\Delta H = T\Delta S$ **(1)**

$T = \Delta H / \Delta S = 492.7 \times 1000 / 542.6$ **(1)**

$= 908$ K **(1)**

penalise missing 1000 by one mark

3

(c) ΔG (b) = ΔG (a)

$(492.7 \times 10^3 - T \times 542.6) = (-24.8 \times 10^3 - T \times 15.2)$ **(1)**

$517.5 \times 10^3 = 527.4$ T **(1)**

$T = 981.2$ K **(1)**

Allow 980 – 982

Penalise missing 1000 by one mark

3

[15]

M6.C

[1]