07 Chemical Energetics I

Set A Answer key

A From the lesson

13 MARKS

1

Reverse the equation: the sign changes, +92

Halve it: ΔH = **+46 kJ mol^{-1}** [1]

2

(a) $C(s) + 2H_2(g) + \frac{1}{2}O_2(g) \rightarrow CH_3OH(l)$ [1]

(b) $C_2H_6(g) + 3\frac{1}{2}O_2(g) \rightarrow 2CO_2(g) + 3H_2O(l)$ [1]

(c) $Mg^{2+}(g) + O^{2-}(g) \rightarrow MgO(s)$ [1]

(d) $\frac{1}{2}Br_2(l) \rightarrow Br(g)$ [1]

3

$q = -(50.0)(4.18)(6.7) = -1400$ J [1]

$n_{H_2O} = 0.0250 \times 1.00 = 0.02500$ mol [1]

$\Delta H_{neut} = -1400 \div 0.02500$ = **−56.0 kJ mol^{-1}** [1]

4

$\Delta H = \Sigma\Delta H_f(\text{products}) - \Sigma\Delta H_f(\text{reactants}) = -85 - (+52 + 0)$ = **−137 kJ mol^{-1}** [1]

5

$H_2(g)$ is an element in its standard state, so its $\Delta H_f^{\ominus} = 0$. [1]

6

$-411 = 107 + 122 + 494 - 349 + LE$ [1]

LE = −411 − 374 = **−785 kJ mol^{-1}** [1]

7

ΔH_{at} forms one mole of Cl atoms: $\frac{1}{2}Cl_2(g) \rightarrow Cl(g)$. Breaking one mole of Cl–Cl bonds gives two moles of atoms. [1]

B Practice

28 MARKS

8

B −60 kJ mol^{-1} [1]

Limiting reagent is hydrochloric acid = $(0.35 \times 0.025) = 0.00875$ mol

$q = (25.0 + 25.0)(4.2)(2.5) = 525$ J

$\Delta H = -(525) \div (0.00875) = -60$ kJ mol^{-1}

9 **B** $\Delta H^{\ominus}_{atomisation}(Si)$, $\Delta H^{\ominus}_{atomisation}(H)$, $\Delta H^{\ominus}_{formation}(SiH_4)$ [1]

10 Using $|LE| \propto \frac{|q_+q_-|}{r_+ + r_-}$:

Mg^{2+} has a higher charge than Na^+, and O^{2-} has a higher charge than Cl^-. Mg^{2+} has a smaller ionic radius than Na^+, and O^{2-} has a smaller ionic radius than Cl^-. [1]

MgO would thus have the largest lattice energy in magnitude (most exothermic). [1]

NOTE Charge is the more dominant factor affecting lattice energies if the ions concerned are from the same period.

11 **(a)** The enthalpy change of combustion is the energy released when 1 mole of a substance is completely burnt in excess oxygen under standard conditions. [1]

(b) Heat absorbed by water = $mc\Delta T = (1750)(4.2)(21.10 - 17.84) = 23960$ J = 23.96 kJ [1]

Heat absorbed by calorimeter = $C\Delta T = (765)(21.10 - 17.84) = 2494$ J = 2.494 kJ [1]

Heat change of combustion of glucose = $-(23.96 + 2.494) = -26.45$ kJ

$n_{glucose} = 2.18 \div (72.0 + 12.0 + 96.0) = 0.01211$ mol

$\Delta H_c(\text{glucose}) = -26.45 \div 0.01211 = -2184$ kJ mol^{-1} = **-2180 kJ mol^{-1}** (3 s.f.) [1]

12 **(a)** More energy is required to break the bonds in the reactants than is given out when the products are formed, due to the much stronger N≡N bond in the reactants. Hence, the reaction is endothermic. [1]

(b)(i) The energy change when 1 mole of a substance is formed from its constituent elements in their standard states at 1 bar, at a specified temperature, usually 298 K. [1]

(ii) $N_2(g) + \frac{5}{2}O_2(g) \rightarrow N_2O_5(g)$ [1]

(iii) By Hess' Law, $\Delta H_f(N_2O_5) = +180 + 2(-57) + (-55)$ [1]

= **+11.0 kJ mol^{-1}** [1]

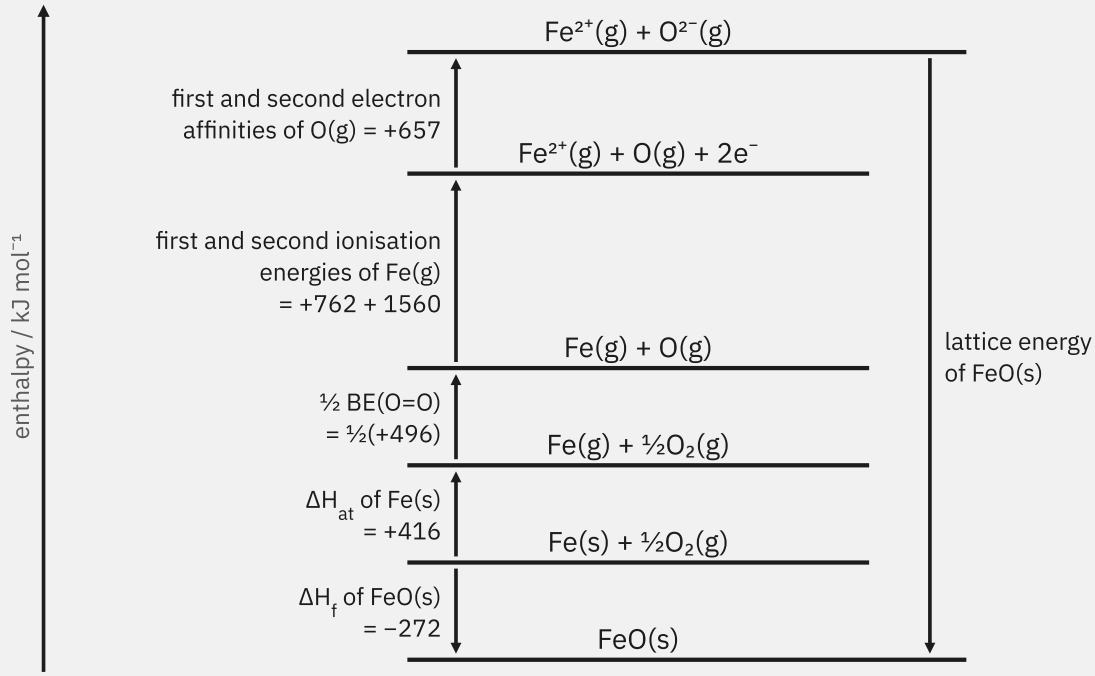
13 **(a)** $C_3H_5(NO_3)_3(l) \rightarrow \frac{3}{2}N_2(g) + \frac{1}{4}O_2(g) + 3CO_2(g) + \frac{5}{2}H_2O(g)$ [1]

(b) $\Delta H_{decomposition} = \Sigma\Delta H_f(\text{products}) - \Sigma\Delta H_f(\text{reactants})$

$= 3(-394) + \frac{5}{2}(-242) - (-364)$

= **-1423 kJ mol^{-1}** [1]

14 **(a)**



By Hess' Law, −272 = +416 + ½(+496) + 762 + 1560 + 657 + LE

LE = **−3915 kJ mol^{-1}** **[3]**

(b)

$$|\text{lattice energy}| \propto \frac{q_+ \times q_-}{r_+ + r_-}$$

Since the anions are the same, and Fe^{2+} and Ca^{2+} have the same charge but Fe^{2+} has a smaller radius, there are stronger ionic bonds *or* greater attraction between Fe^{2+} and O^{2-}. **[1]**

Hence, the lattice energy of FeO is more exothermic *or* more negative than that of CaO. **[1]**

15 **(a)(i)**

$K_2CO_3(s) + 2HCl(aq) \rightarrow 2KCl(aq) + CO_2(g) + H_2O(l)$ **[1]**

(ii)

Heat released = mcΔT = 30.0 × 4.18 × 5.20 = 652.1 J

M_r of K_2CO_3 = 2(39.1) + 12.0 + 3(16.0) = 138.2

$n_{K_2CO_3}$ = 2.76 ÷ 138.2 = 0.01997 mol **[1]**

$n_{HCl} = \frac{30}{1000} \times 2$ = 0.06 mol, hence HCl is in excess.

ΔH_1 = −652.1 ÷ 0.01997 = −32650 J mol^{-1} = **−32.7 kJ mol^{-1}** **[1]**

(b)(i)

$KHCO_3(s) + HCl(aq) \rightarrow KCl(aq) + CO_2(g) + H_2O(l)$ **[1]**

(ii)

Heat absorbed = 30.0 × 4.18 × 3.70 = 464.0 J

M_r of $KHCO_3$ = 39.1 + 1.0 + 12.0 + 3(16.0) = 100.1

n_{KHCO_3} = 2.00 ÷ 100.1 = 0.01998 mol, and HCl is in excess. **[1]**

ΔH_2 = +464.0 ÷ 0.01998 = +23220 J mol^{-1} = **+23.2 kJ mol^{-1}** **[1]**

(c)

$$2KHCO_3(s) \rightarrow K_2CO_3(s) + H_2O(l) + CO_2(g) \quad (2\Delta H_r)$$

Both sides react with $2HCl(aq)$ to give $2KCl(aq) + 2H_2O(l) + 2CO_2(g)$: $2\Delta H_2$ from $2KHCO_3(s)$, ΔH_1 from $K_2CO_3(s)$.

By Hess' Law, $2\Delta H_r = 2\Delta H_2 - \Delta H_1 = +79.1$ kJ mol^{-1} **[1]**

Heat change for the decomposition of 1 mole of $KHCO_3$ = **+39.6 kJ mol^{-1}** (3 s.f.) **[1]**