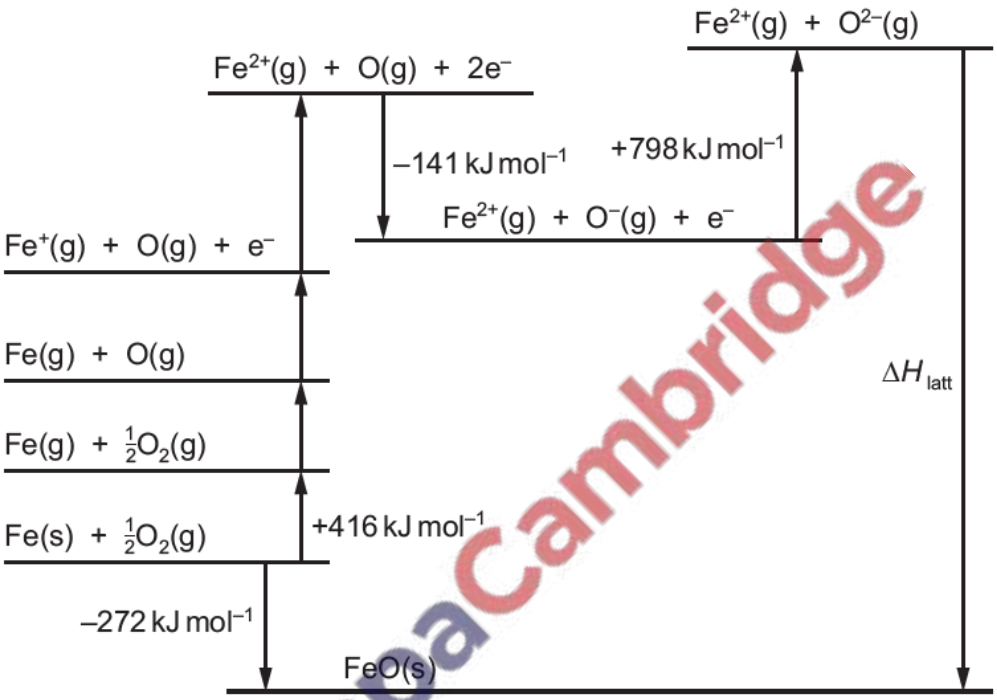
1. March/2021/Paper_42/No.2

(a) Iron(II) compounds are generally only stable in neutral, non-oxidising conditions.

It is difficult to determine the lattice energy of FeO experimentally.

(i) Use data from the *Data Booklet* and this Born–Haber cycle to calculate the lattice energy, ΔH_{latt}, of FeO(s) in kJ mol^{-1}.



ΔH_{latt}FeO(s) = ... kJ mol^{-1} [2]

(ii) Most naturally occurring samples of iron(II) oxide are found as the mineral wüstite.

Wüstite has formula $Fe_{20}O_x$. It contains both Fe^{2+} and Fe^{3+} ions.

90% of the iron is present as Fe^{2+} and 10% is present as Fe^{3+}.

Deduce the value of *x*.

x = ... [1]

(iii) State and explain how the lattice energy of FeO(s) compares to the lattice energy of CaO(s).

.....

.....

.....

.....

..... [2]

(b) Heating of FeO results in the formation of Fe_3O_4, as shown.

reaction 1 $4FeO \rightarrow Fe + Fe_3O_4$

Each formula unit of Fe_3O_4 contains one Fe^{2+} and two Fe^{3+} ions.

(i) Show how reaction 1 can be described as a disproportionation reaction.

.....

.....

..... [1]

$Fe_3O_4(l)$ can be electrolysed using inert electrodes to form Fe.

(ii) Write the half-equation for the reaction that occurs at the anode during the electrolysis of $Fe_3O_4(l)$.

..... [1]

(iii) Calculate the maximum mass of iron metal formed when $Fe_3O_4(l)$ is electrolysed for six hours using a current of 50A.

Assume the one Fe^{2+} and two Fe^{3+} ions are discharged at the same rate.

mass of iron = ... g [3]

(c) $LiFePO_4$ can be used in lithium-ion rechargeable batteries.

When the cell is charging, lithium reacts with a graphite electrode to form LiC_6.

When the cell is discharging, the half-equations for the two processes that occur are as follows.

anode half-equation $LiC_6 \rightarrow 6C + Li^+ + e^-$

cathode half-equation $Li^+ + FePO_4 + e^- \rightarrow LiFePO_4$

(i) State one possible advantage of developing cells such as lithium-ion rechargeable batteries.

..... [1]

(ii) Use the cathode half-equation to determine the change, if any, in oxidation states of lithium and iron at the **cathode** during discharging.

metal	change in oxidation state during discharging	
	from	to
lithium		
iron		

[1]

(iii) Write the equation for the overall reaction that occurs when this cell is discharging.

..... [1]

[Total: 13]

2. June/2021/Paper_42/No.4

(a) (i) Define the term *lattice energy*.

.....

.....

..... [2]

(ii) Use the following data to calculate a value for the enthalpy change of solution of copper(II) chloride, $CuCl_2(s)$. You might find it helpful to construct an energy cycle.

enthalpy change of hydration of Cl^- = –378 kJ mol^{-1}
enthalpy change of hydration of Cu^{2+} = –2099 kJ mol^{-1}
lattice energy of $CuCl_2(s)$ = –2824 kJ mol^{-1}

enthalpy change of solution of $CuCl_2(s)$ = ... kJ mol^{-1} [2]

(iii) The enthalpy change of hydration of Ca^{2+} is –1579 kJ mol^{-1}.

Use the *Data Booklet* to suggest why there is a big difference in the values of ΔH_{hyd} for Ca^{2+} and Cu^{2+}.

.....

.....

..... [2]

(b) (i) Identify the substances formed at the anode and at the cathode during the electrolysis of saturated $CaCl_2(aq)$.

at the anode .....

at the cathode .....
[1]

(ii) Calcium can be produced by the electrolysis of molten calcium chloride, $CaCl_2(l)$.

Calculate the mass, in g, of Ca formed when a current of 0.75A passes through $CaCl_2(l)$ for 60 minutes.
[A_r: Ca, 40.1]

mass of Ca = ... g [2]

3.

(c) (i) Explain what is meant by the term *entropy of a system*.

.....

..... [1]

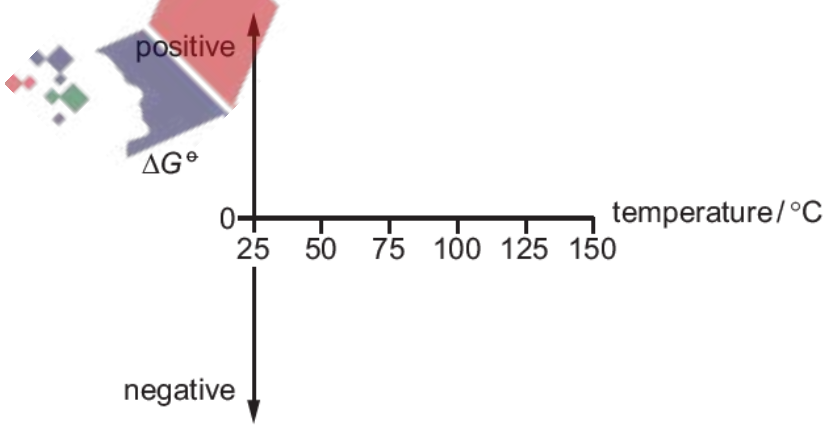
(ii) Place one tick (✓) in each row of the table to show the sign of each entropy change, ΔS.

process	ΔS is negative	ΔS is zero	ΔS is positive
$NaCl$ dissolving in water			
water solidifying to ice			

[1]

(iii) The evaporation of one mole of water has a standard Gibbs free energy change, $\Delta G^{\ominus}$, of +8.6 kJ at 25 °C.

Sketch a graph on the axes to show how $\Delta G^{\ominus}$ changes for this process between 25 °C and 150 °C at 101 kPa.



[2]

(d) The reaction between A and B is feasible at low temperatures but is **not** feasible at high temperatures.

$$A + B \rightleftharpoons C + D$$

Deduce the signs of ΔH and ΔS for this reaction and explain why the feasibility changes with temperature.

sign of ΔH = ... sign of ΔS = ...

.....

.....

.....

..... [2]

[Total: 15]