Oxford Cambridge and RSA

A Level Chemistry A

H432/03 Unified chemistry

Question Set 16

1 This question is about copper(II) sulfate, $CuSO_4$, and sodium thiosulfate, $Na_2S_2O_3$.

(a) The enthalpy change of reaction, $\Delta_r H$, for converting anhydrous copper(II) sulfate to hydrated copper(II) sulfate is difficult to measure directly by experiment.

Reaction 5.1
$CuSO_4(s) + 5H_2O(l) \rightarrow CuSO_4 \cdot 5H_2O(s)$ $\Delta_r H$

The enthalpy changes of solution of anhydrous and hydrated copper(II) sulfate can be measured by experiment. The reactions are shown below.

In the equations, 'aq' represents an excess of water.

Reaction 5.2
$CuSO_4(s) + aq \rightarrow Cu^{2+}(aq) + SO_4^{2-}(aq)$ $\Delta_{sol}H(CuSO_4(s))$

Reaction 5.3
$CuSO_4 \cdot 5H_2O(s) + aq \rightarrow Cu^{2+}(aq) + SO_4^{2-}(aq)$ $\Delta_{sol}H(CuSO_4 \cdot 5H_2O(s))$

Experiment 1
A student carries out an experiment to find $\Delta_{sol}H(CuSO_4(s))$ for **reaction 5.2**.

Student's method
- Weigh a bottle containing $CuSO_4(s)$ and weigh a polystyrene cup.
- Add about 50 cm^3 of water to the polystyrene cup and measure its temperature.
- Add the $CuSO_4(s)$, stir the mixture, and measure the final temperature.
- Weigh the empty bottle and weigh the polystyrene cup with final solution.

Mass readings

Mass of bottle + $CuSO_4(s)$ / g	28.04
Mass of empty bottle / g	20.06
Mass of polystyrene cup / g	23.43
Mass of polystyrene cup + final solution / g	74.13

Temperature readings

Initial temperature of water / °C	20.5
Temperature of final solution / °C	34.0

Experiment 2
The student carries out a second experiment with $CuSO_4 \cdot 5H_2O$ (**reaction 5.3**). The student uses the same method as in **Experiment 1**.

The student calculates $\Delta_{sol}H(CuSO_4 \cdot 5H_2O(s))$ as +8.43 kJ mol^{-1}

(i)* Calculate $\Delta_{sol}H(CuSO_4(s))$ for **reaction 5.2** and determine the enthalpy change of reaction **5.1**, $\Delta_r H$.

Assume that the specific heat capacity, *c*, of the solution is the same as for water.

Show your working, including an energy cycle linking the enthalpy changes. **[6]**

(ii) The thermometer had an uncertainty in each temperature reading of ±0.1 °C.

The student calculates a 20% uncertainty in the temperature change in **Experiment 2**.

Calculate the temperature change in **Experiment 2**. **[1]**

(b) The standard enthalpy change of reaction, $\Delta_r H^{\ominus}$, and the standard free energy change, $\Delta G^{\ominus}$, for converting anhydrous sodium thiosulfate to hydrated sodium thiosulfate are shown below.

$$Na_2S_2O_3(s) + 5H_2O(l) \rightarrow Na_2S_2O_3{\bullet}5H_2O(s) \qquad \Delta_r H^{\ominus} = -55.8\,kJ\,mol^{-1}$$
$$\Delta G^{\ominus} = -16.1\,kJ\,mol^{-1}$$

Standard entropies are given in the table.

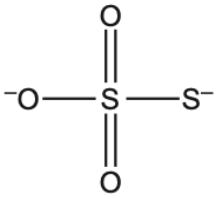
Compound	$S^{\ominus}$ / J K^{-1} mol^{-1}
$Na_2S_2O_3{\bullet}5H_2O(s)$	372.4
$H_2O(l)$	69.9

Determine the **standard** entropy, $S^{\ominus}$, of anhydrous sodium thiosulfate, $Na_2S_2O_3(s)$.

Give your answer to **3** significant figures.

$S^{\ominus}$ = ... J K^{-1} mol^{-1} **[4]**

(c) Sodium thiosulfate contains the thiosulfate ion, $S_2O_3^{2-}$.
The displayed formula of $S_2O_3^{2-}$ can be shown as below.



thiosulfate ion

(i) Predict the O–S–S bond angle and name of the shape of the thiosulfate ion. **[1]**

(ii) In some of its reactions, the thiosulfate ion forms the tetrathionate ion, $S_4O_6^{2-}$.

The $S_4O_6^{2-}$ ion is a 'dimer' of $S_2O_3^{2-}$.

Draw a displayed formula for the $S_4O_6^{2-}$ ion. **[1]**

Total Marks for Question Set 16: 13