Past-paper walk-through

Introduction to Acid-Base Reactions ▪ 4.8

eXercise

Questions in this set

- 2016 Q2

Reading the mark scheme

- **B1** a mark that stands on its own – the point is either made or not.
- **M1** a *method* mark: the right approach, even if the number is wrong.
- **A1** an *answer* mark, and it usually needs its M mark first.
- **C1** a working mark on the way to the answer.
- // separates answers the examiner accepts equally.
- **ecf** = error carried forward: a later part is marked on your own earlier answer.
- **owtte** = "or words to that effect" – the wording need not match.

Question 2

2016 ▪ Q2

$$NaHCO_3(s) + HC_2H_3O_2(aq) \rightarrow NaC_2H_3O_2(aq) + H_2O(l) + CO_2(g)$$

A student designs an experiment to study the reaction between $NaHCO_3$ and $HC_2H_3O_2$. The reaction is represented by the equation above. The student places 2.24 g of $NaHCO_3$ in a flask and adds 60.0 mL of 0.875 M $HC_2H_3O_2$. The student observes the formation of bubbles and that the flask gets cooler as the reaction proceeds.

(a) Identify the reaction represented above as an acid-base reaction, precipitation reaction, or redox reaction. Justify your answer.

Question 2

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(b) Based on the information above, identify the limiting reactant. Justify your answer with calculations.

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(c) The student observes that the bubbling is rapid at the beginning of the reaction and gradually slows as the reaction continues. Explain this change in the reaction rate in terms of the collisions between reactant particles.

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(d)(i) In thermodynamic terms, a reaction can be driven by enthalpy, entropy, or both. Considering that the flask gets cooler as the reaction proceeds, what drives the chemical reaction between $NaHCO_3(s)$ and $HC_2H_3O_2(aq)$? Answer by drawing a circle around one of the choices below.

Enthalpy only Entropy only Both enthalpy and entropy

(d)(ii) Justify your selection in part (d)(i) in terms of ΔG°.

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(e) The HCO_3^- ion has three carbon-to-oxygen bonds. Two of the carbon-to-oxygen bonds have the same length and the third carbon-to-oxygen bond is longer than the other two. The hydrogen atom is bonded to one of the oxygen atoms. In the box below, draw a Lewis electron-dot diagram (or diagrams) for the HCO_3^- ion that is (are) consistent with the given information.

[Empty box provided for the student to draw the Lewis electron-dot diagram(s).]

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A student designs an experiment to study the reaction between $NaHCO_3$ and $HC_2H_3O_2$. The reaction is represented by the equation above. The student places 2.24 g of $NaHCO_3$ in a flask and adds 60.0 mL of 0.875 M $HC_2H_3O_2$. The student observes the formation of bubbles and that the flask gets cooler as the reaction proceeds.

(f) A student prepares a solution containing equimolar amounts of $HC_2H_3O_2$ and $NaC_2H_3O_2$. The pH of the solution is measured to be 4.7. The student adds two drops of 3.0 M $HNO_3(aq)$ and stirs the sample, observing that the pH remains at 4.7. Write a balanced, net-ionic equation for the reaction between $HNO_3(aq)$ and the chemical species in the sample that is responsible for the pH remaining at 4.7.

Solution 2

(a)

Mark scheme

- It is an acid-base reaction: the weak acid HC2H3O2 reacts with the weak base HCO3—, with HC2H3O2 donating a proton. (Equivalently: no solid precipitates, so it is not a precipitation reaction; no oxidation numbers change, so it is not a redox reaction.) 1 point for identifying the reaction as acid-base, 1 point for a valid justification.

Solution 2

(b)

Mark scheme

- 2.24 g NaHCO3 $\times$ (1 mol / 84.0 g) $=$ 0.0267 mol NaHCO3. 60.0 mL $\times$ (0.875 mol HC2H3O2 / 1000 mL) $=$ 0.0525 mol HC2H3O2. NaHCO3(s) and HC2H3O2(aq) react in a 1:1 ratio, so the smaller mole amount, NaHCO3(s), is the limiting reactant. 1 point for calculating the number of moles of each reactant, 1 point for correctly identifying NaHCO3 as the limiting reactant, consistent with the calculation.

Solution 2

(c)

Mark scheme

- As the reaction proceeds, both reactants are consumed and their concentrations decrease; collisions between reactant particles become less frequent as concentrations decrease, so the reaction rate slows. 1 point for a valid explanation in terms of collision frequency between reactant particles.

Solution 2

(d)(i)

Mark scheme

- 'Entropy only' should be circled. Because the flask gets cooler as the reaction proceeds, the reaction is endothermic and cannot be driven by a favorable enthalpy change — it must be driven by entropy. 1 point for circling 'Entropy only'.

Solution 2

(d)(ii)

Mark scheme

- $\Delta G^\circ = \Delta H^\circ - T\Delta S^\circ$; a reaction is thermodynamically favorable when ΔG° is negative. Since the reaction is endothermic (flask gets cooler, ΔH° is positive), enthalpy does not help make ΔG° negative, so the reaction is not driven by enthalpy. Because the reactants contain no gas while one product (CO2) is a gas, ΔS° must be positive, which helps make ΔG° negative — so the reaction is entropy-driven. 1 point for a valid justification referencing the signs of ΔH°, ΔS°, and ΔG°.

Solution 2

(e) Mark scheme

- A correct Lewis structure for HCO3— has a central C bonded to three O atoms: one C=O double bond, one C—O single bond to an O bearing three lone pairs (charge —1 on that O), and one C—O single bond to the O—H oxygen (two lone pairs on that O), with the H attached to that same oxygen. Because two C-to-O bonds are equal length and the third (C—OH) is longer, resonance exists between the two equivalent non-OH oxygens — shown either as two resonance structures or as one structure with a double-headed resonance arrow between those two oxygens. 1 point for a correct Lewis structure of HCO3—, 1 point for indicating resonance between the two equivalent (non-OH) oxygens.

Solution 2

(f)

Mark scheme

- $C2H3O2- + H3O+ \rightarrow HC2H3O2 + H2O$ (equivalently: $C2H3O2- + H+ \rightarrow HC2H3O2$). 1 point for a correct, balanced net-ionic equation showing the acetate ion neutralizing the added $H3O+/H+$, which is why the pH remains at 4.7 (buffer action).