2.23 Bond Energies, Cells and Fuel Cells: 30-minute Pack

AQA 8464 · Calculator allowed · about 30 minutes

Total Marks

Name: _____ Date: ____ / ____ / _____

Answer ALL questions. Show all your working.

1 Calculate the mass of water produced when 0.500 mol of hydrogen reacts completely with oxygen in a fuel cell according to $2H_2 + O_2 \rightarrow 2H_2O$. Relative formula mass $H_2O = 18.0$.

(a) Calculate the mass of water produced from 0.500 mol H_2. **(2)**

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(Total for Question 1 is 2 marks)

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2 The hydrogen-oxygen fuel cell has the overall reaction: $2H_2(g) + O_2(g) \rightarrow 2H_2O(l)$.

Write the two half-equations that occur at the anode and the cathode in a hydrogen-oxygen fuel cell operating with acid electrolyte. Indicate which half-equation goes at the anode.

(a) Write the half-equation at the anode and state it is the anode. **(2)**

(b) Write the cathode half-equation. **(1)**

(Total for Question 2 is 3 marks)

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3 Higher tier only. Inside a car engine, the high temperatures and pressures allow nitrogen and oxygen from the air to react together: $N_2 + O_2$ -> 2NO. Bond energies: N-N (triple bond, in N_2) = 945 kJ/mol, O=O = 498 kJ/mol, N=O = 630 kJ/mol.

(a) Calculate the overall energy change for this reaction. **(3)**

(b) State whether this reaction is exothermic or endothermic, and use this to explain why nitrogen monoxide only forms in significant amounts at the high temperatures inside a car engine, rather than at room temperature. **(2)**

(Total for Question 3 is 5 marks)

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4 Higher tier only. Inside a hydrogen fuel cell with an alkaline electrolyte, hydrogen is oxidised at the negative electrode and oxygen is reduced at the positive electrode.

(a) Write the half equation for the reaction at the negative electrode. **(2)**

(b) Write the half equation for the reaction at the positive electrode. **(2)**

(c) Show how adding these two half equations together, cancelling the electrons and any other species common to both sides, gives the overall equation for the reaction in a hydrogen fuel cell. **(2)**

(Total for Question 4 is 6 marks)

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5 Higher tier only. Hydrogen reacts with iodine: $H_2 + I_2 \rightarrow 2HI$. This reaction has an overall energy change of +52 kJ/mol. Bond energies: H-H = 436 kJ/mol, I-I = 152 kJ/mol.

(a) Calculate the total energy needed to break the bonds in the reactants. **(1)**

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(b) The overall energy change of a reaction is equal to the energy needed to break the bonds in the reactants minus the energy released forming the bonds in the products. Use this, and your answer to part a, to calculate the bond energy of the H-I bond. **(3)**

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(c) Explain, referring to your calculations, why this reaction is described as endothermic. **(1)**

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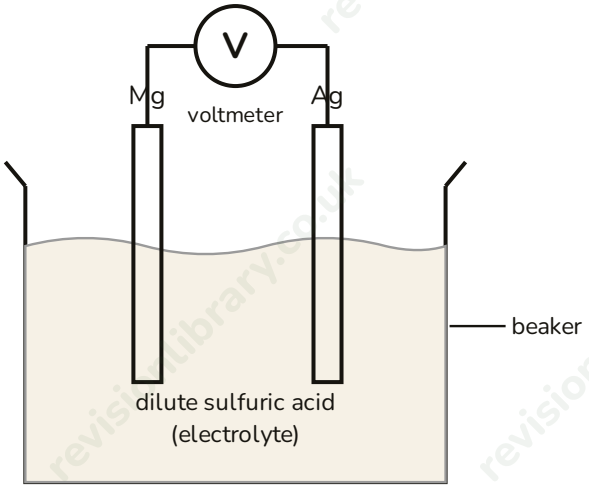
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(Total for Question 5 is 5 marks)

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6 A simple chemical cell can be made by placing two different metal electrodes into an electrolyte and connecting them with wires and a voltmeter, as shown in Figure 1. A student, Owusu, sets up a cell using a magnesium electrode and a silver electrode dipped into dilute sulfuric acid.

Figure 1: a simple chemical cell



(a) State two components, other than the two metal electrodes, that are needed to complete this simple chemical cell. **(2)**

(b) Explain why this cell produces a voltage between the magnesium and silver electrodes. **(2)**

(c) Predict, giving a reason based on the reactivity series, whether replacing the silver electrode with a copper electrode (keeping the magnesium electrode and electrolyte the same) would increase or decrease the voltage produced. **(2)**

(Total for Question 6 is 6 marks)

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Mark scheme · 2.23 Bond Energies, Cells and Fuel Cells: 30-minute Pack

Question 1

(a) uses mole ratio: 2 mol H_2 produce 2 mol H_2O so moles H_2O = moles H_2 = 0.500 **M1**

(a) mass = 0.500 x 18.0 = 9.00 g cao **A1**

(a) Answer: 9.00 g

Question 2

(a) anode half-equation: H_2 -> $2H^+$ + 2e- **M1**

(a) states this occurs at the anode **A1**

(a) Answer: Anode: H_2 -> $2H^+$ + 2e- (this is at the anode)

(b) cathode half-equation: O_2 + $4H^+$ + 4e- -> $2H_2O$ **B1**

(b) Answer: Cathode: O_2 + $4H^+$ + 4e- -> $2H_2O$

Question 3

(a) bonds broken = 945 + 498 = 1443 oe **M1**

(a) bonds made = 2 x 630 = 1260 oe **M1**

(a) +183 kJ/mol cao **A1**

(a) Answer: +183 kJ/mol

(b) endothermic (positive energy change), ft from a **M1**

(b) at the high temperatures inside a car engine, particles collide more frequently and with more energy, so more collisions have enough energy to overcome the activation energy needed for this endothermic reaction oe **A1**

(b) Answer: Endothermic. At the high temperatures inside a car engine, particles collide more often and with more energy, so enough collisions have sufficient energy to overcome the activation energy needed - this does not happen at room temperature.

Question 4

(a) correct species shown: H_2, OH^-, H_2O, e- oe **M1**

(a) correctly balanced: $2H_2$ + $4OH^-$ -> $4H_2O$ + 4e- cao **A1**

(a) Answer: $2H_2$ + $4OH^-$ -> $4H_2O$ + 4e-

(b) correct species shown: O_2, H_2O, e-, OH^- oe **M1**

(b) correctly balanced: O_2 + $2H_2O$ + 4e- -> $4OH^-$ cao **A1**

(b) Answer: O_2 + $2H_2O$ + 4e- -> $4OH^-$

(c) adds the two half equations and cancels the 4e-, the $4OH^-$ and 2 of the 4 mol H_2O common to both sides oe **M1**

(c) $2H_2$ + O_2 -> $2H_2O$ cao **A1**

(c) Answer: $2H_2$ + O_2 -> $2H_2O$

Question 5

(a) 588 kJ/mol (436 + 152) cao **B1**

(a) Answer: 588 kJ/mol

(b) rearranges to find energy released forming bonds: 588 - 52 = 536 kJ/mol oe **M1**

(b) recognises 536 kJ/mol corresponds to 2 mol of H-I bonds (in 2 mol HI), so divides by 2 oe **M1**

(b) 268 kJ/mol cao **A1**

(b) Answer: 268 kJ/mol

(c) because the energy needed to break the bonds in the reactants (588 kJ/mol) is greater than the energy released forming the bonds in the products (536 kJ/mol), so overall energy is absorbed from the surroundings oe **B1**

(c) Answer: The energy needed to break the bonds in the reactants (588 kJ/mol) is greater than the energy released forming the bonds in the products (536 kJ/mol), so overall energy is absorbed from the surroundings - the reaction is endothermic.

Question 6

(a) an electrolyte (a solution that can conduct electricity/allow ions to move) oe **B1**

(a) a wire (external circuit) connecting the electrodes, together with a device such as a voltmeter to measure/use the voltage produced oe **B1**

(a) Answer: An electrolyte (here, dilute sulfuric acid) and a wire (external circuit), together with a voltmeter to measure the voltage produced.

(b) the two metals have different tendencies to lose electrons (react to different extents) oe **M1**

(b) this produces a difference in electrical potential between the two electrodes, which drives electrons around the external circuit when it is completed oe **A1**

(b) Answer: Magnesium and silver have different tendencies to lose electrons, so a difference in electrical potential (a voltage) is set up between the two electrodes, which drives electrons around the external circuit.

(c) copper is more reactive than silver (silver is the least reactive of the two) oe **M1**

(c) so the difference in reactivity between magnesium and copper is smaller than between magnesium and silver, so the voltage would decrease oe **A1**

(c) Answer: The voltage would decrease, because copper is more reactive than silver, so the difference in reactivity between magnesium and copper is smaller than between magnesium and silver.

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