2.23 Bond Energies, Cells and Fuel Cells: Test Pack

AQA 8464 · Calculator allowed · about 45 minutes

Total Marks

Name: _____ Date: ____ / ____ / _____

Answer ALL questions. Show all your working.

1 Give the definition of the term 'average bond enthalpy' used in bond energy calculations.

(a) Give the definition of 'average bond enthalpy'. **(1)**

(Total for Question 1 is 1 mark)

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2 A hydrogen fuel cell is a type of chemical cell. Unlike a battery, it does not store its reactants inside the cell itself.

(a) State how the fuel (hydrogen) and oxygen are supplied to a hydrogen fuel cell. **(1)**

(b) Contrast this with how the reactants are held in a non-rechargeable battery. **(1)**

(c) State what happens to the electricity a hydrogen fuel cell can produce if the supply of hydrogen and oxygen is maintained continuously. **(1)**

(Total for Question 2 is 3 marks)

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3 Some vehicle manufacturers are developing cars powered by hydrogen fuel cells, as an alternative to both petrol/diesel engines and rechargeable battery-electric vehicles.

(a) Give one advantage of a hydrogen fuel-cell vehicle compared with a petrol vehicle. **(1)**

(b) Give one advantage of a hydrogen fuel-cell vehicle compared with a rechargeable battery-electric vehicle. **(1)**

(c) Suggest two reasons why hydrogen fuel-cell vehicles are not yet widely used on UK roads, despite these advantages. **(2)**

(d) Hydrogen used in fuel cells is often produced industrially from natural gas (a fossil fuel), rather than by the electrolysis of water using renewable electricity. Explain why this affects how 'clean' hydrogen fuel-cell vehicles really are overall. **(2)**

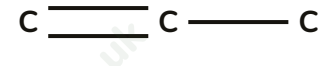
(Total for Question 3 is 6 marks)

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4 Higher tier only. Propene reacts with hydrogen, in the presence of a nickel catalyst, to form propane: $C_3H_6 + H_2 \rightarrow C_3H_8$. Figure 3 shows the carbon skeleton of propene and propane, the number of hydrogen atoms bonded to each carbon atom, and the hydrogen molecule, H_2.

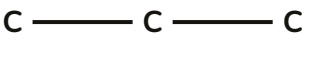
Figure 3: carbon skeletons of propene, propane and hydrogen

Propene, C3H6



(2 H) (1 H) (3 H)

Propane, C3H8



(3 H) (2 H) (3 H)

Hydrogen, H2

Key: two parallel lines between carbons = a C=C double bond; (n H) = number of hydrogen atoms bonded to that carbon.

(a) Using Figure 3, state the total number of each of the following bond types present in one molecule of propene (C_3H_6) and one molecule of hydrogen (H_2), combined: C-H bonds, C-C bonds, C=C bonds and H-H bonds. **(3)**

(b) Calculate the total energy needed to break all of these bonds, using the bond energies C-H = 413 kJ/mol, C-C = 347 kJ/mol, C=C = 612 kJ/mol and H-H = 436 kJ/mol. **(2)**

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(c) Using Figure 3, state the number of C-H bonds and C-C bonds in one molecule of propane (C_3H_8), and calculate the total energy released when all of these bonds are formed. **(2)**

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(d) Calculate the overall energy change for this reaction, and state whether it is exothermic or endothermic. **(2)**

.....

(Total for Question 4 is 9 marks)

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5 In a simple chemical cell, the more reactive metal electrode loses electrons more readily than the less reactive metal electrode.

(a) State which electrode, the more reactive metal or the less reactive metal, acts as the negative electrode in a simple cell. **(1)**

(b) State whether conventional current in the external circuit flows in the same direction as electron flow, or the opposite direction. **(1)**

(c) Explain why the less reactive metal electrode becomes the positive electrode of the cell. **(2)**

(Total for Question 5 is 4 marks)

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6 A non-rechargeable battery is described as 'flat' once it can no longer produce a useful voltage, whereas a rechargeable battery can be restored by connecting it to a charger.

(a) Explain, in terms of the chemicals inside it, why a non-rechargeable battery goes flat. **(2)**

(b) Explain how connecting a rechargeable battery to a charger restores its ability to produce a voltage. **(2)**

(Total for Question 6 is 4 marks)

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7 A candidate uses average bond enthalpies to estimate the enthalpy change for the reaction: $CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(l)$.
Use bond enthalpies: C-H = 413 kJ mol^{-1}, O=O (double bond) = 498 kJ mol^{-1}, C=O (in CO_2) = 799 kJ mol^{-1}, O-H = 463 kJ mol^{-1}.
Calculate the approximate DeltaH for the reaction. Show working and state the sign and unit.

(a) Calculate DeltaH using bond enthalpies with substitution and arithmetic. **(3)**

(Total for Question 7 is 3 marks)

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8 A student measures the bond enthalpy of the C-H bond using different organic molecules and obtains a range of values. Explain why bond enthalpies are quoted as averages and why values for a given bond may differ between molecules.

(a) Explain why bond enthalpies are quoted as averages and why they vary between molecules. **(3)**

(Total for Question 8 is 3 marks)

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Mark scheme · 2.23 Bond Energies, Cells and Fuel Cells: Test Pack

Question 1

(a) the average energy required to break one mole of a particular bond in gaseous molecules, measured under standard conditions, oe **B1**

(a) Answer: The average energy required to break one mole of a particular bond in gaseous molecules under standard conditions.

Question 2

(a) they are supplied continuously from external tanks/an external supply, rather than being stored inside the cell oe **B1**

(a) Answer: Hydrogen and oxygen are supplied continuously to the cell from external tanks, rather than being stored inside the cell itself.

(b) in a non-rechargeable battery, all of the reactants needed are sealed inside the battery from the start oe **B1**

(b) Answer: In a non-rechargeable battery, all the reactants are sealed inside the battery from the moment it is made.

(c) the fuel cell will keep on producing electricity (a voltage) for as long as hydrogen and oxygen keep being supplied; it does not go flat like a battery oe **B1**

(c) Answer: It will keep producing electricity for as long as hydrogen and oxygen keep being supplied - unlike a battery, it does not go flat.

Question 3

(a) no carbon dioxide (or other polluting exhaust gases) is produced at the point of use - only water is produced oe **B1**

(a) Answer: No carbon dioxide or other polluting gases are produced at the point of use - only water.

(b) refuelling with hydrogen takes only a few minutes, much faster than recharging a battery oe **B1**

(b) Answer: Refuelling with hydrogen takes only a few minutes, much faster than recharging a battery.

(c) there are very few hydrogen refuelling stations, so drivers cannot rely on being able to refuel easily oe **B1**

(c) hydrogen is difficult and expensive to store and transport safely, since it is flammable and has a very low density (it must be compressed or cooled) oe **B1**

(c) Answer: There are very few hydrogen refuelling stations in the UK, and hydrogen is difficult, expensive and potentially hazardous to store and transport, since it is flammable and has a very low density.

(d) producing hydrogen from natural gas releases carbon dioxide during production, even though the fuel cell itself only produces water oe **M1**

(d) so the overall environmental impact of a hydrogen fuel-cell vehicle depends on how the hydrogen was produced, not just on how it is used in the vehicle oe **A1**

(d) Answer: Producing hydrogen from natural gas releases carbon dioxide, even though the fuel cell itself only produces water, so the true environmental benefit depends on how the hydrogen was produced, not just how it is used.

Question 4

(a) 6 C-H bonds (2 + 1 + 3, from the hydrogen atom counts shown) oe **B1**

(a) 1 C-C bond and 1 C=C bond oe **B1**

(a) 1 H-H bond (from the H_2 molecule) oe **B1**

(a) Answer: 6 C-H bonds, 1 C-C bond, 1 C=C bond and 1 H-H bond.

(b) (6 x 413) + 347 + 612 + 436, ft from a oe **M1**

(b) 3873 kJ/mol cao **A1**

(b) Answer: 3873 kJ/mol

(c) 8 C-H bonds (3 + 2 + 3) and 2 C-C bonds identified oe **M1**

(c) 3998 kJ/mol cao [(8 x 413) + (2 x 347) = 3304 + 694 = 3998] **A1**

(c) Answer: 8 C-H bonds and 2 C-C bonds; total energy released = 3998 kJ/mol.

(d) 3873 - 3998, ft from b and c **M1**

(d) -125 kJ/mol; exothermic cao **A1**

(d) Answer: -125 kJ/mol; exothermic

Question 5

(a) the more reactive metal (electrode) oe **B1**

(a) Answer: The more reactive metal is the negative electrode.

(b) the opposite direction (conventional current flows from positive to negative through the external circuit; electrons flow from negative to positive) oe **B1**

(b) Answer: Conventional current flows in the opposite direction to electron flow: from the positive electrode to the negative electrode through the external circuit, while electrons flow from negative to positive.

(c) the less reactive metal loses electrons less readily than the more reactive metal oe **M1**

(c) so electrons flow towards it through the external circuit (relative to the more reactive electrode), making it the positive terminal oe **A1**

(c) Answer: The less reactive metal loses electrons less readily than the more reactive metal, so electrons flow towards it through the external circuit, making it the positive electrode.

Question 6

(a) one (or more) of the reactants inside the cell has been completely used up oe **M1**

(a) so the chemical reaction that produces the voltage can no longer take place oe **A1**

(a) Answer: One of the reactants inside the battery has been completely used up, so the chemical reaction that produces the voltage can no longer take place.

(b) an external electrical current/supply from the charger reverses the chemical reaction inside the battery oe **M1**

(b) this regenerates (re-forms) the original reactants, so the battery can produce a voltage again oe **A1**

(b) Answer: The charger passes an external electrical current through the battery, reversing the chemical reaction and regenerating the original reactants, so the battery can produce a voltage again.

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Question 7

(a) method: DeltaH = sum bonds broken - sum bonds formed with substitution: broken = (4 x C-H) + (2 x O=O) = (4 x 413) + (2 x 498) **M1**

(a) forms: (2 x C=O) + (4 x O-H) = (2 x 799) + (4 x 463) and correct arithmetic **M1**

(a) final value = -802 kJ mol^{-1} (allow -792 to -812) cao **A1**

(a) Answer: -802 kJ mol^{-1}

Question 8

(a) states that bond enthalpies depend on the chemical environment so energy to break a C-H bond is not identical in all molecules **M1**

(a) explains that different neighbouring atoms, bond order and hybridisation change bond strength and so measured values differ **M1**

(a) concludes that tables give average values to provide useful estimates for calculations, oe **A1**

(a) Answer: Because the energy to break a C-H bond depends on the molecule and its environment (neighbouring atoms, bond order, hybridisation), measured values differ. Therefore tables quote average bond enthalpies so chemists have useful approximate values for calculations.

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