Chemistry · Electrochemistry

Applications of Galvanic Cells and Producing Electrical Energy

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questions	sets	pages

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Multiple choice questions — 38 questions

1 A primary cell used in hearing aids.

Which of the following statements is NOT correct for this cell?

(A) One of the products of its reaction is a non-transition element.

(B) The oxidizing agent is a transition element.

(C) Spontaneous oxidation and reduction take place in it.

(D) The concentration of the electrolyte does not change.

---

2 In the mercury cell, all of the following are correct, except .....

(A) No reduction of the oxygen of the cathode takes place.

(B) The electrolyte used is KOH

(C) The reaction equation: $Zn + Hg^{2+} \rightarrow Zn^{2+} + Hg$

(D) It can store electrical energy again in the form of chemical energy.

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3 Which of the following happens in the mercury cell when it is operating?

(A) Each zinc atom loses two electrons.

(B) Each zinc ion loses two electrons.

(C) Each mercury atom gains an electron.

(D) Each mercury ion gains an electron.

---

4 The following two reactions take place in one of the galvanic cells:

$Zn(s) + 2OH^-(aq) \rightarrow ZnO(s) + H_2O(l) + 2e^-$ $E^\circ = X$ V

$HgO(s) + H_2O(l) + 2e^- \rightarrow Hg(l) + 2OH^-(aq)$ $E^\circ = +0.0977$ V

Which of the following gives the value of (X), and what is the type of this galvanic cell?

(A) 1.1323 V / primary cell.

(B) 1.1323 V / secondary cell.

(C) 1.2523 V / primary cell.

(D) 1.2523 V / secondary cell.

---

5 From the following statements:

(1): Suitable for use in devices that work with a small voltage.

(2): The anode is made of zinc and the cathode of mercury(II) oxide.

(3): The electrolyte is a paste of KO_2 and $Zn(OH)_2$

(4): Anode reaction: $Zn + H_2O \rightarrow ZnO + 2OH^- + 2e^-$

Which of the following describes the mercury cell?

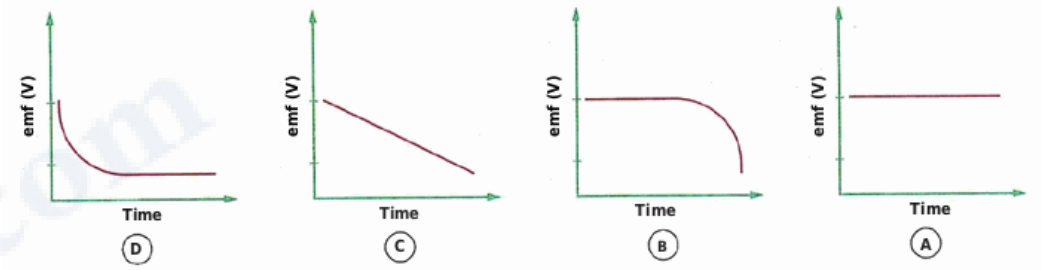
(A) (1), (2).

(B) (2), (3).

(C) (3), (4).

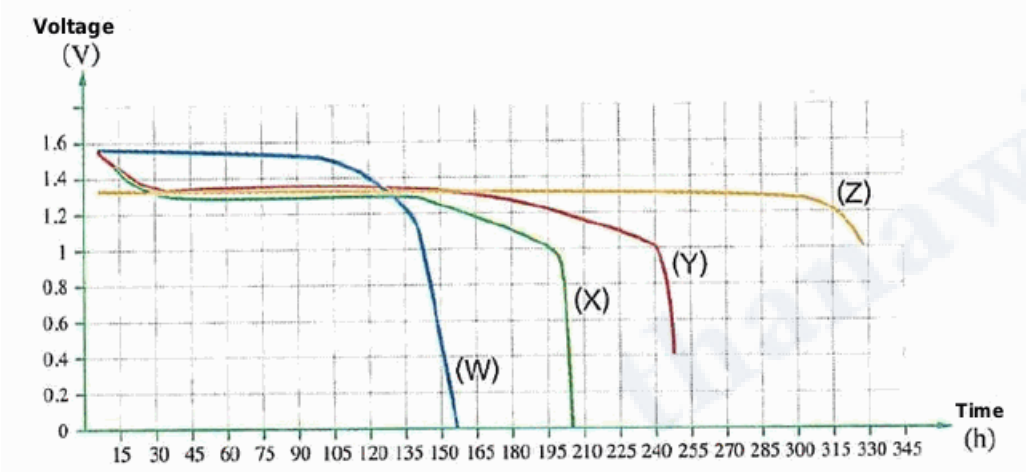
(D) (2), (4).

6 Which of the following graphs shows one of the properties of the dry cell?



7 The following graph shows what happens to the voltages of four galvanic cells with time as they discharge:

Which curve represents the mercury cell?



(A) (W). (B) (X). (C) (Y). (D) (Z).

8 Which of the following statements describes the fuel cell?

(A) A primary cell that stores electrical energy.

(B) Its electrolyte is sulphuric acid.

(C) It produces electrical energy and water.

(D) A secondary cell supplied with external fuel.

9 In the fuel cell, reduction takes place for .....

(A) $H_2(g)$ (B) $H_2O(l)$ (C) $OH^-(aq)$ (D) $O_2(g)$

10 Which of the following happens in the fuel cell?

(A) OH^- ions move from the anode to the cathode through the electrolyte.

(B) H^+ ions move from the anode to the cathode through the electrolyte.

(C) Electrons move from the cathode to the anode during charging.

(D) Electrons move from the cathode to the anode during discharging.

---

11 A cell that does not store energy and needs a continuous supply of fuel to work.

Which of the following describes this cell?

(A) The reaction $O_2 + 2e^- \rightarrow 2O^{2-}$ takes place in it.

(B) The electrolyte used in it (KOH) is anhydrous.

(C) It works at a high temperature.

(D) The fuel used in it is not suitable as a rocket-launching fuel.

---

12 A fuel cell uses 1500 L of hydrogen gas (at STP).

What is the volume and name of the other gas needed to use up all the hydrogen at the same conditions of pressure and temperature?

(A) 1500 L of oxygen gas.

(B) 1500 L of chlorine gas.

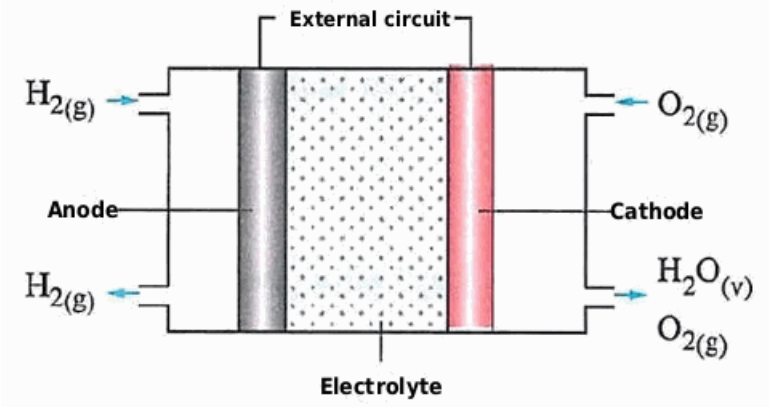
(C) 750 L of oxygen gas.

(D) 750 L of chlorine gas.

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13 In the primary galvanic cell shown in the opposite figure:

What happens to the pH value around the two electrodes with time?



(A) The pH increases around the anode and decreases around the cathode.

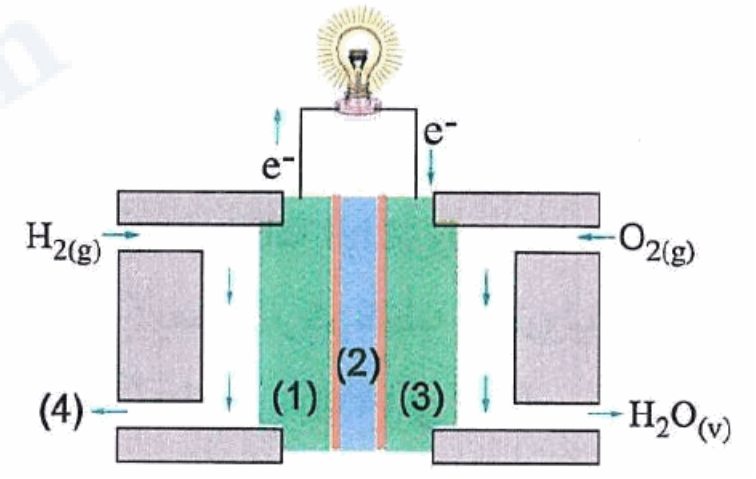
(B) The pH increases around both electrodes.

(C) The pH decreases around the anode and increases around the cathode.

(D) The pH decreases around both electrodes.

14 The opposite figure shows the structure of the fuel cell.

Which of the following describes what happens in each of the regions (1), (2), (3), (4)?



(A) (1) oxidation of H_2, (2) movement of H^+ ions, (3) reduction of O_2, (4) excess H_2

(B) (1) oxidation of H_2, (2) movement of electrons, (3) reduction of O_2, (4) $H_2O(v)$

(C) (1) oxidation of H^+ ions, (2) movement of H^+ ions, (3) reduction of O^{2-} ions, (4) excess H_2

(D) (1) oxidation of H^+ ions, (2) movement of H^+ ions, (3) reduction of O^{2-} ions, (4) $H_2O(v)$

---

15 When the lead-acid battery discharges .....

(A) lead is formed.

(B) $PbSO_4$ is used up.

(C) sulphuric acid is used up.

(D) SO_2 gas is given off.

---

16 Which of the following represents the oxidation reaction when the lead accumulator is operating?

(A) $Pb \rightarrow Pb^{2+} + 2e^-$ (B) $Pb^{2+} + 4e^- \rightarrow Pb$ (C) $Pb^{2+} + 2e^- \rightarrow Pb$ (D) $Pb \rightarrow Pb^{4+} + 4e^-$

---

17 Using the lead accumulator for a long time leads to .....

(A) deposition of lead(II) sulphate at the cathode and lead dioxide at the anode.

(B) an increase in the deposition of lead(II) sulphate at both the cathode and the anode.

(C) an increase in the density of the electrolyte solution.

(D) deposition of lead(II) sulphate at the anode only.

---

18 What is the mass of 250 cm^3 of the electrolyte of a fully charged lead-acid battery?

(A) 250 g (B) 300 g (C) 325 g (D) 340 g

19 In the charging reaction of the lead-acid accumulator, ...

(A) only oxidation of lead(II) sulphate takes place.

(B) oxidation and reduction of lead(II) sulphate take place.

(C) only reduction of lead(IV) oxide takes place.

(D) oxidation and reduction of lead(IV) oxide take place.

20 All of the following happen when the lead accumulator discharges, except .....

(A) Lead(II) sulphate is deposited at both the anode and the cathode.

(B) The density of the electrolyte decreases.

(C) The accumulator acts as an electrolytic cell.

(D) PbO_2 is reduced to Pb^{2+}

21 What happens when the lead-acid battery discharges?

(A) The amount of Pb^{4+} ions used up is inversely proportional to the operating time.

(B) The amount of Pb^{2+} ions formed is directly proportional to the operating time.

(C) The anode acts as the positive electrode.

(D) The number of moles of H_2SO_4 formed in the electrolyte increases.

22 All of the following are properties of lead(II) sulphate, except that it .....

(A) does not dissolve in water.

(B) forms at the anode when the accumulator is charged.

(C) is a white solid.

(D) has its lead oxidized and reduced when the accumulator is charged.

23 Which of the following substances undergo a change in oxidation number during charging and discharging of the lead accumulator?

(A) Spongy lead (✓), lead(IV) oxide (✓), sulphuric acid (✗)

(B) Spongy lead (✓), lead(IV) oxide (✓), sulphuric acid (✓)

(C) Spongy lead (✗), lead(IV) oxide (✗), sulphuric acid (✗)

(D) Spongy lead (✗), lead(IV) oxide (✗), sulphuric acid (✓)

---

24 The following statements may describe the redox reactions in the lead accumulator:

(1): Pb is oxidized to $PbSO_4$ in the discharging reaction.

(2): PbO_2 is reduced to $PbSO_4$ in the charging reaction.

(3): $PbSO_4$ is oxidized to PbO_2 in the charging reaction.

(4): $PbSO_4$ is reduced to Pb in the discharging reaction.

Which of the following gives the statements that describe the reactions taking place in the lead accumulator?

(A) (1), (2). (B) (2), (3). (C) (3), (4). (D) (1), (3).

---

25 What happens to the density of the electrolyte and its pH, respectively, when the lead accumulator is charged?

(A) Increases / increases.

(B) Increases / decreases.

(C) Decreases / decreases.

(D) Decreases / increases.

---

26 A lead-acid cell has an anode oxidation potential of 0.36 V, a cathode reduction potential of 1.69 V, and the percentage of acid in the electrolyte is 38% [H_2SO_4 = 98 g/mol]

What are the density of the electrolyte and its molar concentration, respectively?

(A) 1.29 g/mL, 0.49 M

(B) 1.29 g/mL, 5 M

(C) 1 g/mL, 5 M

(D) 1 g/mL, 0.49 M

---

27 Which of the following gives the transition metals used (as metals or compounds) in making rechargeable galvanic cells?

(A) Nickel and cadmium.

(B) Nickel and cobalt.

(C) Zinc and mercury.

(D) Lead and zinc.

---

28 Which of the following gives the anode and cathode reactions in a lead-acid cell, given that the mass of one litre of the battery solution is 0.5 kg?

(A) Anode: $Pb \rightarrow Pb^{2+} + 2e^-$ ($E^\circ = 0.36$ V), cathode: $Pb^{4+} + 2e^- \rightarrow Pb^{2+}$ ($E^\circ = 1.69$ V)

(B) Anode: $Pb \rightarrow Pb^{2+} + 2e^-$ ($E^\circ = 0.36$ V), cathode: $Pb^{4+} + 2e^- \rightarrow Pb^{2+}$ ($E^\circ = 1.39$ V)

(C) Anode: $Pb \rightarrow Pb^{2+} + 2e^-$ ($E^\circ = 0.26$ V), cathode: $Pb^{4+} + 2e^- \rightarrow Pb^{2+}$ ($E^\circ = 1.69$ V)

(D) Anode: $Pb \rightarrow Pb^{2+} + 2e^-$ ($E^\circ = 0.26$ V), cathode: $Pb^{4+} + 2e^- \rightarrow Pb^{2+}$ ($E^\circ = 1.39$ V)

---

29 All of the following are properties of the lithium-ion battery, except that it .....

(A) contains an anhydrous electrolyte.

(B) stores a large amount of energy relative to its size.

(C) works at high temperatures.

(D) is a dry secondary cell.

---

30 The following two reactions represent the discharging of a (silver–zinc) cell:

$Zn(s) + 2OH^-(aq) \rightarrow ZnO(s) + H_2O(l) + 2e^-$

$Ag_2O(s) + H_2O(l) + 2e^- \rightarrow 2Ag(s) + 2OH^-(aq)$

Which of the following gives the substances used up during discharging of the cell and the equation of the overall reaction?

(A) Substances used up: Ag_2O, Zn / Equation: $Zn(s) + 2OH^-(aq) + Ag_2O(s) \rightarrow ZnO(s) + 2Ag(s) + 2OH^-(aq)$

(B) Substances used up: Ag_2O, Zn / Equation: $Zn(s) + Ag_2O(s) \rightarrow 2Ag(s) + ZnO(s)$

(C) Substances used up: Zn only / Equation: $Zn(s) + Ag_2O(s) \rightarrow 2Ag(s) + ZnO(s)$

(D) Substances used up: Zn only / Equation: $Zn(s) + 2OH^-(aq) + Ag_2O(s) \rightarrow ZnO(s) + 2Ag(s) + 2OH^-(aq)$

---

31 What change happens to the ion of the transition element while the lithium-ion battery is being charged?

(A) Oxidation, and the number of unpaired electrons increases.

(B) Oxidation, and the number of unpaired electrons decreases.

(C) Reduction, and the number of paired electrons increases.

(D) Reduction, and the number of paired electrons decreases.

---

32 Which of the following describes the movement of lithium ions and the movement of electrons in the lithium-ion battery?

(A) Lithium ions move in the same direction as the electrons during charging.

(B) Lithium ions move in the opposite direction to the electrons during charging.

(C) Lithium ions move in the opposite direction to the electrons during discharging.

(D) The movement of lithium ions is not related to the movement of electrons during discharging.

---

33 From the following assumption and its explanation:

Assumption: There is a thin insulator between the anode and the cathode.

Explanation: To allow lithium ions to move from the negative electrode to the positive electrode during discharging.

Which of the following describes the lithium-ion battery?

(A) Assumption (✓), explanation (✓)

(B) Assumption (✓), explanation (✗)

(C) Assumption (✗), explanation (✓)

(D) Assumption (✗), explanation (✗)

---

34 The anode material is the same in .....

(A) the fuel cell and the mercury cell.

(B) the lithium-ion battery and the lead-acid battery.

(C) the Daniell cell and the mercury cell.

(D) the fuel cell and the lead-acid battery.

---

35 Which of the following describes the type of reactions taking place in the fuel cell and in the lithium-ion cell?

(A) Fuel cell: spontaneous only, lithium-ion cell: spontaneous only

(B) Fuel cell: spontaneous and non-spontaneous, lithium-ion cell: spontaneous and non-spontaneous

(C) Fuel cell: spontaneous only, lithium-ion cell: spontaneous and non-spontaneous

(D) Fuel cell: spontaneous and non-spontaneous, lithium-ion cell: spontaneous only

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36 The galvanic cells in which the pH value of the electrolyte is greater than 7 are .....

(A) the mercury cell and the lithium-ion battery.

(B) the mercury cell and the fuel cell.

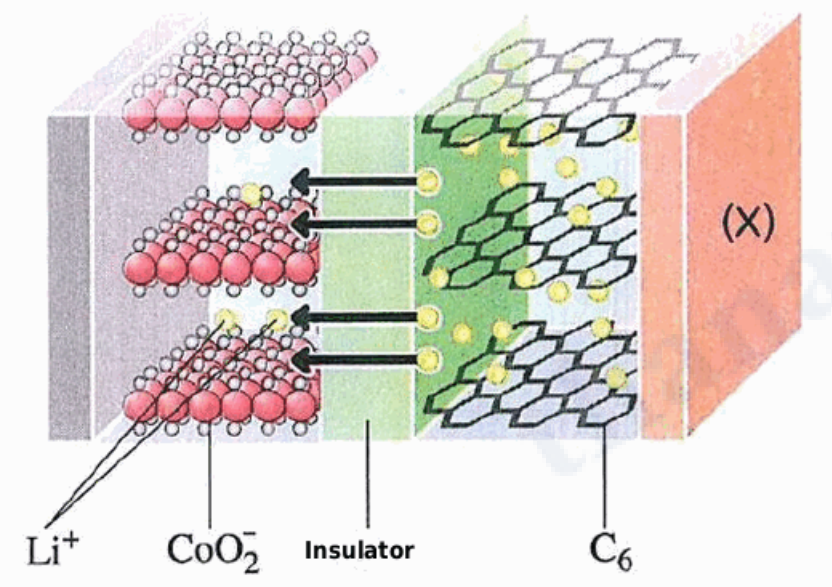
(C) the fuel cell and the lithium-ion battery.

(D) the lithium-ion battery and the lead accumulator.

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37 The opposite figure represents a lithium-ion battery.

Does the figure show charging or discharging, and what role does electrode (X) play in this case?



(A) The battery is charging, electrode (X) acts as the cathode

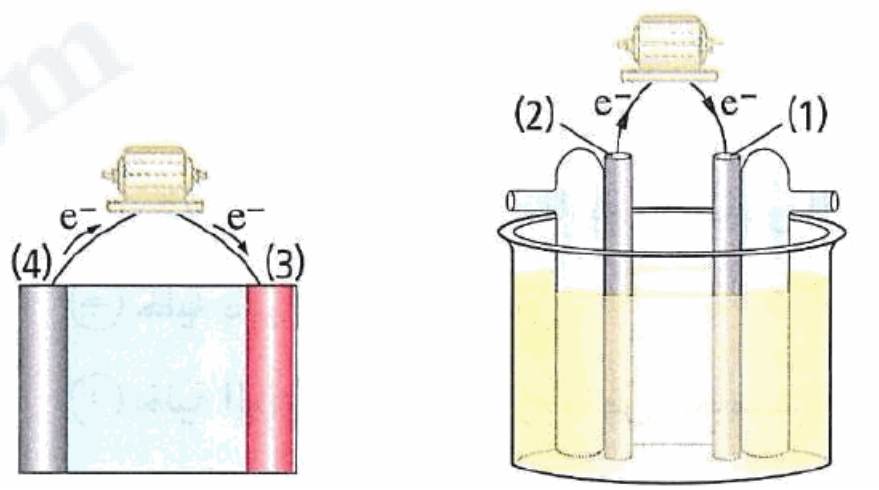
(B) The battery is discharging, electrode (X) acts as the anode

(C) The battery is charging, electrode (X) acts as the anode

(D) The battery is discharging, electrode (X) acts as the cathode

---

38 The opposite figure represents a fuel cell and a lithium-ion battery during discharging.
Which of the following is correct?



(A) (1): cathode, (3): anode.

(B) (3): anode, (4): cathode.

(C) (2): anode, (4): cathode.

(D) (2): anode, (3): cathode.

Essay questions — 7 questions

1 The mercury cell is one of the primary cells:

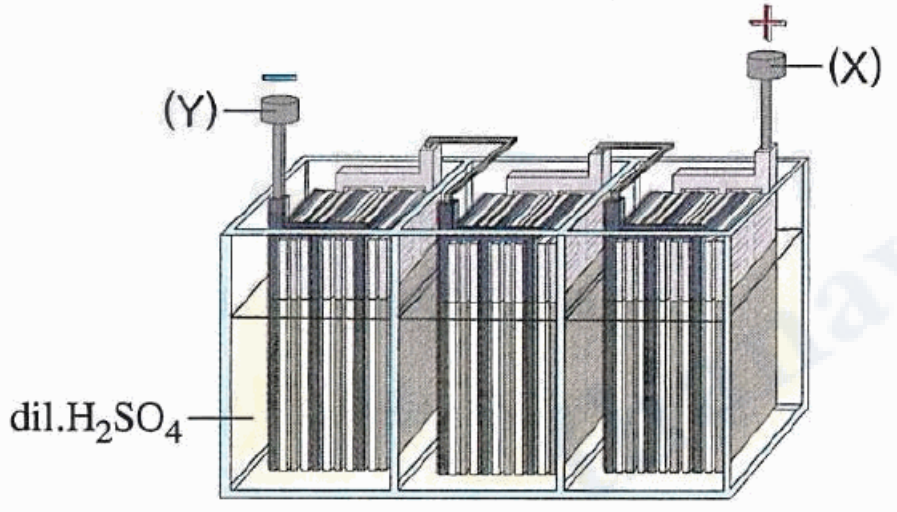
(1) Why is the mercury cell described as an alkaline cell?

(2) Why is the zinc used in the anode of this cell in the form of a powder?

2 From the opposite figure, write the reaction that takes place at:

(1) electrode (X) when the battery discharges.

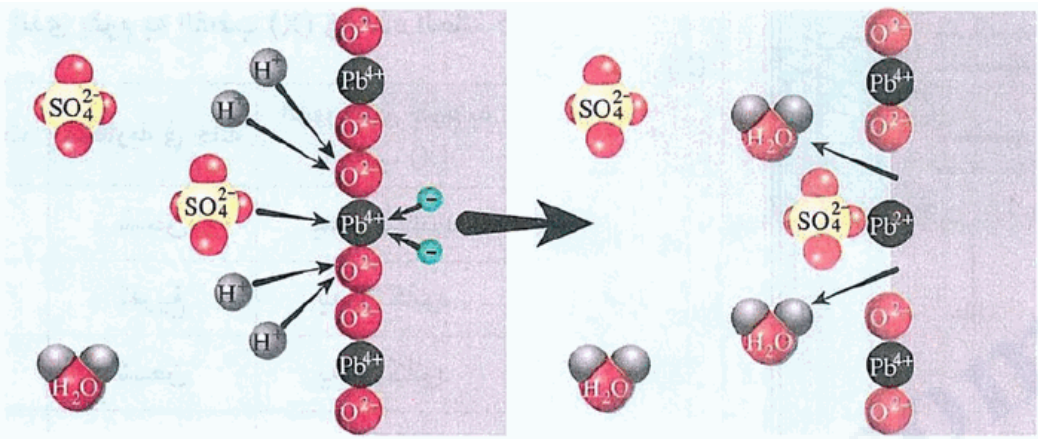
(2) electrode (Y) when the battery is recharged.



3 The following figure shows one of the reactions that take place in the lead accumulator:

(1) Write the symbolic equation of the reaction that takes place.

(2) Does this reaction take place at the cathode or the anode? Explain.



4 75 mL of 0.2 M sodium hydroxide solution was used to titrate a 1.5 mL sample of the electrolyte of a charged lead accumulator:

(1) Calculate the concentration of this electrolyte.

(2) Is the concentration of the electrolyte greater in the charged or in the uncharged accumulator? Explain.

5 Explain, writing the equation of the reaction, the type of ions that are:

(1) produced at the cathode in the fuel cell.

(2) used up at the cathode in the lead accumulator.

6 Lithium ions move through the electrolyte of a lithium-ion battery towards the positive electrode in case (X), and their path is reversed in case (Y):

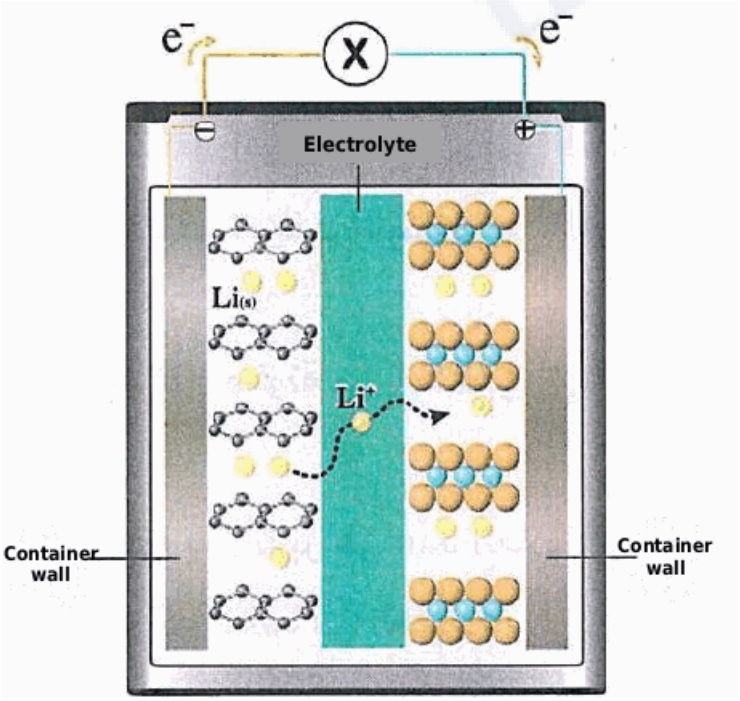
(1) Write the symbolic equation of the reaction that takes place in case (X).

(2) Does case (Y) represent charging or discharging? Explain.

7 The opposite figure shows the structure of a lithium-ion battery:

(1) Does device (X) represent a mobile phone or a source of electric current? Explain.

(2) Write the equation of the reaction that takes place in this case.



Past exam questions — 29 questions

1 The following reaction takes place in a galvanic half-cell: $X^{n+} + ne^- \rightarrow X$

Which of the following gives element (X) and the use of this cell?

(A) Element: Hg, use: hearing aids

(B) Element: Pb, use: medical devices

(C) Element: H_2, use: obtaining drinking water for astronauts

(D) Element: O_2, use: spacecraft

---

2 Which of the following is correct during the discharging of a lithium-ion cell?

(A) Lithium ions move from the positive electrode to the negative electrode.

(B) Electrons move from the positive electrode to the negative electrode.

(C) Lithium ions move to the negative electrode.

(D) Lithium ions move to the positive electrode.

---

3 Cell (R) is made of the two electrodes (X) and (Y), where:

$E°(X^{3+}/X) = -1.670$ V

$E°(Y^{2+}/Y) = +0.34$ V

Which of the following gives the number of cells (R) that must be connected in series to obtain a battery with an emf of 8.05 V, and the role of each electrode in the cell?

(A) 4 cells, with (Y) as the anode and (X) as the cathode.

(B) 6 cells, with (Y) as the anode and (X) as the cathode.

(C) 4 cells, with (X) as the anode and (Y) as the cathode.

(D) 6 cells, with (X) as the anode and (Y) as the cathode.

---

4 Which of the following processes represents a redox reaction that can be used to obtain electrical energy?

(A) Conversion of lead sulphate into lead(IV) ions in the car battery.

(B) Electroplating some car parts with chromium metal to protect them from rusting.

(C) Electrolysis of water into hydrogen and oxygen.

(D) Combination of hydrogen with oxygen to form water.

---

5 Which of the following happens in the lead-acid battery during charging?

(A) Pb^{2+} ions change into Pb^{4+} ions at the cathode.

(B) Pb^{2+} ions change into Pb at the anode.

(C) Electrons move from the negative electrode to the positive electrode.

(D) Electrons move from the anode to the cathode.

---

6 Which of the following is correct for the negative hydroxide ions in the fuel cell?

(A) They are used up by the reduction reaction and formed by the oxidation reaction.

(B) They are used up by the oxidation reaction and formed by the reduction reaction.

(C) Their concentration decreases at the cathode.

(D) Their concentration increases at the anode.

---

7 Which of the following is correct for both the fuel cell and the mercury cell?

(A) Both are cells that convert the chemical energy stored in them into electrical energy.

(B) Reduction takes place in each of them at the negative electrode.

(C) The components of both cells are used up during operation.

(D) Both are alkaline cells and the concentration of the electrolyte does not change during operation.

---

8 When the lead accumulator discharges.

Which of the following happens as a result?

(A) The mass of the anode decreases and the mass of the cathode increases.

(B) The density of the solution increases and lead(II) ions form at the anode.

(C) The density of the solution decreases and the mass of the anode increases.

(D) The density of the solution increases and lead(II) ions form at the cathode.

---

9 A car battery (X), with an acid density of 1.19 g/cm^3, is connected in parallel to another car battery (Y), with an acid density of 1.29 g/cm^3.

Which of the following happens in this case?

(A) Pb^{2+} ions are oxidized to Pb^{4+} ions at the positive electrode of battery (X), and lead atoms are oxidized to Pb^{2+} ions at the positive electrode of battery (Y).

(B) Pb^{2+} ions are reduced to Pb atoms at the positive electrode of battery (X), and Pb^{2+} ions are reduced to Pb atoms at the positive electrode of battery (Y).

(C) Pb^{2+} ions are oxidized to Pb^{4+} ions at the negative electrode of battery (X), and lead atoms are oxidized to Pb^{2+} ions at the positive electrode of battery (Y).

(D) Pb^{2+} ions are reduced to Pb atoms at the negative electrode of battery (X), and Pb^{4+} ions are reduced to Pb^{2+} ions at the positive electrode of battery (Y).

---

10 Which of the following choices describes what happens to the hydrogen of the hydroxyl group while the fuel cell is operating?

(A) It is oxidized and loses 4 electrons.

(B) It is oxidized and loses an electron.

(C) It is reduced and gains 4 electrons.

(D) It is neither oxidized nor reduced.

---

11 What happens when the two electrodes of the lithium battery are connected to an external electrical source with a slightly higher voltage?

(A) The (Li^+) ion gains an electron at the cathode.

(B) The lithium atom loses an electron at the cathode.

(C) The (Li^+) ion gains an electron at the anode.

(D) The lithium atom gains an electron at the anode.

---

12 In the mercury cell, when the zinc container is replaced by a nickel container under standard conditions,

which of the following is correct, given that mercury comes after hydrogen in the electrochemical series?

(A) The emf value decreases

(B) The emf value increases

(C) Nickel acts as the cathode.

(D) The direction of the current in the wire changes.

---

13 In the two opposite cells:

(1) $Y + X^+ \rightarrow Y^+ + X$, emf = 0.4 V

(2) $W + Z^+ \rightarrow W^+ + Z$, emf = 0.9 V

When the like electrodes of cells (1) and (2) are connected together in parallel.

Which of the following answers is correct?

(A) Cell (1) is galvanic, cell (2) is electrolytic, electrode (Y) is the anode.

(B) Cell (1) is galvanic, cell (2) is electrolytic, electrode (Z) is the cathode.

(C) Cell (2) is galvanic, cell (1) is electrolytic, electrode (W) is the anode

(D) Cell (2) is galvanic, cell (1) is electrolytic, electrode (Z) is the anode

---

14 The reaction that takes place at the anode of a primary galvanic cell is .....

(A) $Ag_2O(s) + Zn(s) \rightarrow ZnO(s) + 2Ag(s)$

(B) $Zn(s) + 2OH^-(aq) \rightarrow ZnO(s) + H_2O(l) + 2e^-$

(C) $Ag_2O(s) + H_2O(l) + 2e^- \rightarrow 2Ag(s) + 2OH^-(aq)$

(D) $ZnO(s) + H_2O(l) + 2e^- \rightarrow Zn(s) + 2OH^-(aq)$

---

15 Which of the following describes the electrical cell that uses the same gaseous fuel as that used in launching rockets?

(A) The reactions inside the cell cannot be controlled.

(B) It does not store any of the energy produced.

(C) It works at a low temperature.

(D) It does not need a continuous supply of gaseous fuel to work.

---

16 The redox reactions in the fuel cell lead to .....

(A) movement of hydroxide ions towards the anode.

(B) movement of hydroxide ions towards the cathode.

(C) conversion of oxygen into hydroxide ions by oxidation.

(D) conversion of hydrogen by reduction into water molecules.

---

17 While the fuel cell is operating.

Which of the following choices is correct?

(A) The concentration of the electrolyte stays constant.

(B) The concentration of the electrolyte decreases.

(C) The pH value of the electrolyte decreases.

(D) The pH value of the electrolyte increases.

---

18 Which of the following is correct when the lead-acid battery discharges?

(A) The concentration of the acid increases and its density decreases.

(B) The concentration of the acid decreases and its density increases.

(C) The oxidation number of the cathode material changes from $(+4)$ to $(+2)$.

(D) The oxidation number of the anode material changes from (0) to $(+4)$.

---

19 In the car battery, the electrode at which the reaction: $PbSO_4 \rightarrow Pb^{4+} + 2e^- + SO_4^{2-}$ takes place is .....

(A) the cathode, during discharging.

(B) the cathode, during charging.

(C) the anode, during discharging.

(D) the anode, during charging.

---

20 Which of the following choices is correct while a lead accumulator is being charged?

(A) The concentration of the electrolyte decreases and lead forms at the anode.

(B) The concentration of the electrolyte increases and lead(II) oxide forms at the cathode.

(C) The concentration of the electrolyte increases and lead forms at the cathode.

(D) The concentration of the electrolyte does not change and lead(IV) oxide forms at the anode.

---

21 When the lead accumulator is charged, all of the following happen, except .....

(A) The concentration of the acid increases.

(B) The mass of water decreases.

(C) The pOH value decreases.

(D) The pH value decreases.

---

22 While a car battery is being charged .....

(A) the emf value of the car battery decreases and the concentration of the acid increases.

(B) the emf value of the car battery increases and the concentration of the acid decreases.

(C) the negative terminal of the external source is connected to the lead electrode.

(D) the positive terminal of the external source is connected to the lead electrode.

---

23 When the lead accumulator is connected to an external electric source with an emf of 14 V, which of the following is correct?

(A) The pOH value of the electrolyte solution decreases.

(B) The pH value of the electrolyte solution decreases.

(C) The oxidation number of lead at the anode increases.

(D) The amount of water in the battery increases.

---

24 In a lead-acid battery, the following data were recorded during discharging:

- Anode potential = +0.36 V
- Cathode potential = +1.69 V
- Hydrometer reading = 1 g/cm^3

So this battery .....

(A) is fully charged, and the battery produces 12 V

(B) needs recharging, and the battery produces 2.05 V after charging.

(C) is fully charged, and the cell produces 12 V

(D) needs recharging, and the cell produces 2.05 V after charging.

---

25 In the lithium-ion battery, lithium ions move through ($LiPF_6$) .....

(A) from the negative anode to the positive cathode during discharging.

(B) from the negative anode to the positive cathode during charging.

(C) from the cathode to the anode during discharging.

(D) from the cathode to the anode during charging.

---

26 Comparing the reducing agent in the mercury cell and in the fuel cell, which of the following is the stronger?

(A) H_2 (B) H^+ (C) Zn^{2+} (D) Zn

27 In the mercury cell and the fuel cell, which of the following is correct?

(A) Oxygen ions in the mercury cell are oxidized.

(B) Oxygen ions in the fuel cell are reduced.

(C) Oxygen ions in the mercury cell are neither oxidized nor reduced.

(D) Oxygen ions in the fuel cell are oxidized.

---

28 Given that the electrode potentials of a secondary galvanic battery are as follows:

$NiO_2 + 2H_2O + 2e^- \rightarrow Ni(OH)_2 + 2OH^-$ $E^\circ = +0.49$ V

$Fe(OH)_2 + 2e^- \rightarrow Fe + 2OH^-$ $E^\circ = -0.88$ V

To fully charge this battery, it is connected to an electrical source with an emf of .....

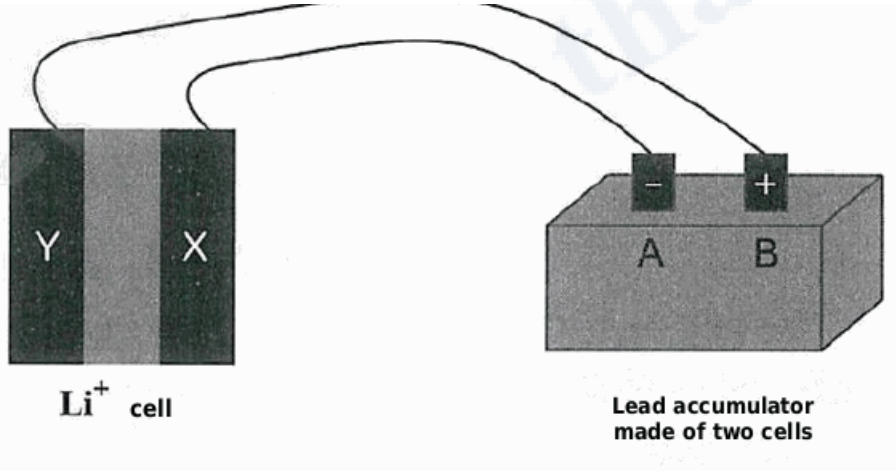
(A) 2 V (B) 1.37 V (C) 220 V (D) 1.3 V

---

29 Study the following figure:

(1) Identify the anode and the cathode in the lithium battery.

(2) State which one (the lead battery or the lithium cell) has spontaneous reactions taking place in it.



Answer key and solutions

Multiple choice questions

1 B	2 D	3 A	4 C	5 A	6 B	7 D	8 C	9 D	10 B
11 C	12 C	13 C	14 A	15 C	16 A	17 B	18 C	19 B	20 C
21 B	22 B	23 A	24 D	25 B	26 B	27 B	28 D	29 C	30 B
31 A	32 A	33 A	34 C	35 C	36 B	37 B	38 D		

1 **Answer (B)**

Mercury cell: $Zn + HgO \rightarrow ZnO + Hg$

Mercury (Hg) is not a transition element, so the oxidizing agent HgO is not a transition element.

2 **Answer (D)**

The mercury cell is a primary cell that cannot be recharged.

So it cannot store electrical energy in the form of chemical energy.

3 **Answer (A)**

$Zn \rightarrow Zn^{2+} + 2e^{-}$, so each zinc atom loses two electrons.

4 **Answer (C)**

emf of the mercury cell = 1.35 V

X + 0.0977 = 1.35, so X = 1.2523 V

The cell is a primary cell that cannot be recharged.

5 **Answer (A)**

Statements (1) and (2) are correct.

The electrolyte (3) is a paste of KOH, not KO_2, and the anode reaction (4) is not balanced.

6 **Answer (B)**

The voltage of the dry cell stays almost constant, then drops suddenly when the reacting substances are used up.

7 **Answer (D)**

The voltage of the mercury cell stays almost constant $(1.35\ \text{V})$ for a long time before it drops suddenly.

This is represented by curve (Z).

8 **Answer (C)**

In the fuel cell, H_2 and O_2 react, producing electrical energy and water.

It is neither a primary nor a secondary cell, because it does not store energy.

9 **Answer (D)**

At the cathode, O_2 is reduced:

$O_2 + 2H_2O + 4e^- \rightarrow 4OH^-$

10 **Answer (B)**

In the fuel cell, H^+ ions move from the anode to the cathode through the electrolyte.

Electrons move through the external circuit from the anode to the cathode.

11 **Answer (C)**

(A) The equation is not balanced $(O_2 + 4e^- \rightarrow 2O^{2-})$.

(B) KOH is an aqueous electrolyte, not an anhydrous one.

(D) Hydrogen is suitable as a rocket-launching fuel.

So (C) is correct: the cell works at a high temperature.

12 **Answer (C)**

$2H_2 + O_2 \rightarrow 2H_2O$

2×22.4 L of H_2 react with 22.4 L of O_2

Volume of oxygen $= (22.4 \times 1500) \div (2 \times 22.4) = 750$ L

13 **Answer (C)**

Anode: $H_2 + 2OH^- \rightarrow 2H_2O + 2e^-$, so OH^- is used up and the pH decreases.

Cathode: $O_2 + 2H_2O + 4e^- \rightarrow 4OH^-$, so OH^- is formed and the pH increases.

14 **Answer (A)**

(1) Anode: oxidation of H_2.

(2) Electrolyte: H^+ ions move through it.

(3) Cathode: reduction of O_2.

(4) The excess hydrogen leaves.

15 **Answer (C)**

On discharging: $Pb + PbO_2 + 2H_2SO_4 \rightarrow 2PbSO_4 + 2H_2O$

Sulphuric acid is used up, and $PbSO_4$ and water are formed.

16 **Answer (A)**

Oxidation at the anode: $Pb \rightarrow Pb^{2+} + 2e^-$ ($PbSO_4$ is formed).

17 **Answer (B)**

During use, $PbSO_4$ forms at both the anode and the cathode, so more of it is deposited.

The density of the electrolyte decreases because the acid is used up.

18 **Answer (C)**

Density of the electrolyte of a fully charged accumulator = 1.3 g/mL

Mass = $1.3 \times 250 = 325$ g

19 **Answer (B)**

On charging, $PbSO_4$ at one electrode changes into PbO_2 (oxidation).

$PbSO_4$ at the other electrode changes into Pb (reduction).

So $PbSO_4$ is both oxidized and reduced on charging.

20 **Answer (C)**

On discharging, the accumulator acts as a galvanic cell, not as an electrolytic cell.

$PbSO_4$ forms at both electrodes, the density of the acid decreases and PbO_2 is reduced to Pb^{2+}.

21 **Answer (B)**

On discharging, Pb is oxidized to Pb^{2+} ($PbSO_4$), so the amount of Pb^{2+} formed increases as the operating time increases.

The anode is the negative electrode, and H_2SO_4 is used up.

22 **Answer (B)**

On charging, $PbSO_4$ changes into Pb and PbO_2, i.e. it is used up, not formed.

On discharging, $PbSO_4$ forms at both the anode and the cathode.

23 **Answer (A)**

Pb: $0 \leftrightarrow +2$, its oxidation number changes.

PbO_2: $+4 \leftrightarrow +2$, its oxidation number changes.

The oxidation numbers of the elements of sulphuric acid do not change.

24 **Answer (D)**

(1) is correct: Pb → $PbSO_4$, oxidation on discharging.

(3) is correct: $PbSO_4$ → PbO_2, oxidation on charging.

(2) and (4) are wrong: PbO_2 is reduced on discharging, and $PbSO_4$ is reduced to Pb on charging.

25 **Answer (B)**

On charging, H_2SO_4 is formed, so the density of the electrolyte increases and the concentration of H^+ increases.

So the pH value decreases.

26 **Answer (B)**

Density of the electrolyte = 1.29 g/mL (cell voltage = 0.36 + 1.69 = 2.05 V, i.e. a fully charged cell).

Mass of H_2SO_4 in 1 L = 1290 × 38 ÷ 100 = 490.2 g

Concentration = 490.2 ÷ 98 = 5 M

27 **Answer (B)**

Nickel and cobalt are elements of the first transition series.

Cadmium, mercury and zinc are in group 2B and are not considered transition elements.

Lead is not a transition element.

28 **Answer (D)**

Density of the solution = 0.5 g/mL, which is less than 1.2 g/mL.

So the battery is not charged, and the potentials are not 0.36 V and 1.69 V.

29 **Answer (C)**

The lithium-ion battery is a dry secondary cell that works at ordinary temperature, and its electrolyte is anhydrous.

30 **Answer (B)**

$Zn + 2OH^- \rightarrow ZnO + H_2O + 2e^-$

$Ag_2O + H_2O + 2e^- \rightarrow 2Ag + 2OH^-$

Adding the two equations and cancelling the common species: $Zn + Ag_2O \rightarrow ZnO + 2Ag$

Zn and Ag_2O are used up.

31 **Answer (A)**

On charging, cobalt ions are oxidized ($Co^{3+} \rightarrow Co^{4+}$).

An electron is lost from a paired orbital, so the number of unpaired electrons increases.

32 **Answer (A)**

On charging, lithium ions move towards the graphite (negative) electrode.

The electrons move through the external circuit in the same direction.

33 **Answer (A)**

The presence of the thin insulator between the anode and the cathode is a correct assumption.

Its explanation is correct, because it allows lithium ions to pass and prevents contact between the two electrodes.

34 **Answer (C)**

The anode in the Daniell cell and the mercury cell is zinc (Zn).

35 **Answer (C)**

Fuel cell: its reaction is spontaneous only, and it is not charged.

Lithium-ion cell: spontaneous on discharging and non-spontaneous on charging.

36 **Answer (B)**

The electrolyte of the mercury cell and the fuel cell is KOH, which is alkaline, so the pH is greater than 7.

37 **Answer (B)**

Li^+ ions move from the graphite (C_6) to CoO_2, and this happens on discharging.

Electrode (X), next to the graphite, is the anode.

38 **Answer (D)**

On discharging, electrons flow from the anode to the cathode through the external circuit.

In the figure: (2) is the anode and (3) is the cathode.

Essay questions

1 **Model answer**

(1) Because the electrolyte used in it (KOH) is alkaline.

(2) To increase its surface area exposed to the reaction, and so increase the rate of the reaction.

2 **Model answer**

(1) When the battery discharges, electrode (X) acts as the cathode:

$PbO_2(s) + 4H^+(aq) + SO_4^{2-}(aq) + 2e^- \rightarrow PbSO_4(s) + 2H_2O(l)$

(2) Electrode (Y) in the charged battery is the lead electrode, which is oxidized; when the battery is recharged, the oxidation is reversed into reduction:

$PbSO_4(s) + 2e^- \rightarrow Pb(s) + SO_4^{2-}(aq)$

3 **Model answer**

(1) $PbO_2(s) + 4H^+(aq) + SO_4^{2-}(aq) + 2e^- \rightarrow PbSO_4(s) + 2H_2O(l)$

(2) At the cathode, because it is a reduction reaction in which electrons are gained.

4 **Model answer**

(1) $2NaOH + H_2SO_4 \rightarrow Na_2SO_4 + 2H_2O$

$(M_b \times V_b) \div n_b = (M_a \times V_a) \div n_a$

$(0.2 \times 75) \div 2 = (M_a \times 1.5) \div 1$

Concentration of the electrolyte $M_a = (0.2 \times 75) \div (1.5 \times 2) = 5$ M

(2) The concentration of the electrolyte is greater in the charged accumulator, because using the battery for a long time dilutes the electrolyte with the water produced by the discharging reactions.

5 **Model answer**

(1) $O_2(g) + 2H_2O(v) + 4e^- \rightarrow 4OH^-(aq)$

Negative hydroxide ions are produced at the cathode.

(2) $PbO_2(s) + 4H^+(aq) + SO_4^{2-}(aq) + 2e^- \rightarrow PbSO_4(s) + 2H_2O(l)$

Positive hydrogen ions and SO_4^{2-} ions are used up at the cathode.

6 **Model answer**

(1) $LiC_6(s) + CoO_2(s) \rightarrow C_6(s) + LiCoO_2(s)$

(2) Charging, because the movement of Li^+ towards the cathode $(-)$ means that a non-spontaneous redox reaction is taking place.

7 **Model answer**

(1) Device (X) represents a mobile phone, because Li^+ ions move from the LiC_6 electrode towards the $LiCoO_2$ electrode when the battery discharges.

(2) $LiC_6(s) + CoO_2(s) \rightarrow C_6(s) + LiCoO_2(s)$

Past exam questions

1	2	3	4	5	6	7	8	9	10
A	D	C	D	D	B	D	C	D	D
11	12	13	14	15	16	17	18	19	20
A	A	C	B	B	A	A	C	D	C
21	22	23	24	25	26	27	28	29	
C	C	B	D	A	D	C	A	—	

1 **Answer (A)**

$X^{n+} + ne^- \rightarrow X$ is the reduction of a metal formed at the cathode.

Mercury ($Hg^{2+} \rightarrow Hg$) is used in the small primary mercury cell for hearing aids.

2 **Answer (D)**

On discharging, lithium ions move through the electrolyte from the anode (negative) to the cathode (positive).

Electrons move from the negative electrode to the positive electrode through the wire.

3 **Answer (C)**

emf = reduction potential of the cathode − reduction potential of the anode = $0.34 - (-1.670) = 2.01$ V

The anode is X because its reduction potential is lower, and the cathode is Y.

Number of cells = $8.05 \div 2.01 = 4$ cells

4 **Answer (D)**

Electrical energy is produced by a spontaneous reaction, which is the combination of H_2 with O_2 (fuel cell).

The other choices need electrical energy (charging, plating or electrolysis).

5 **Answer (D)**

On charging, the battery acts as an electrolytic cell.

Pb^{2+} is oxidized to Pb^{4+} at the anode, and Pb^{2+} is reduced to Pb at the cathode.

Electrons always move from the anode to the cathode.

6 **Answer (B)**

Anode: $H_2 + 2OH^- \rightarrow 2H_2O + 2e^-$ (OH^- is used up in oxidation).

Cathode: $O_2 + 2H_2O + 4e^- \rightarrow 4OH^-$ (OH^- is formed in reduction).

7 **Answer (D)**

The fuel cell does not store its components, and it is supplied with fuel continuously.

The electrolyte in both cells is KOH, and its concentration does not change because there is no net consumption or formation of it.

8 **Answer (C)**

On discharging: $Pb + PbO_2 + 2H_2SO_4 \rightarrow 2PbSO_4 + 2H_2O$

$PbSO_4$ forms at both electrodes, so their masses increase, and the acid is used up, so the density of the solution decreases.

9 **Answer (D)**

Battery (Y) has the higher voltage, so it discharges and charges battery (X).

At the negative electrode of battery (X), Pb^{2+} is reduced to Pb.

At the positive electrode of battery (Y), Pb^{4+} is reduced to Pb^{2+}.

10 **Answer (D)**

In the fuel cell: $H_2 + 2OH^- \rightarrow 2H_2O + 2e^-$

The oxidation number of hydrogen in OH^- is +1 and in H_2O is +1, so it does not change.

11 **Answer (A)**

The external source with the higher voltage charges the battery.

On charging, Li^+ moves to the cathode and gains an electron, becoming Li (reduction).

12 **Answer (A)**

The oxidation potential of nickel is lower than that of zinc.

The cathode did not change, so the emf value decreases (emf = reduction potential of the cathode + oxidation potential of the anode).

13 **Answer (C)**

The cell with the larger emf (cell 2 = 0.9 V) is galvanic and charges the other one.

Cell (1) is electrolytic.

In cell (2), W is oxidized and is the anode.

14 **Answer (B)**

The anode is the electrode at which oxidation takes place.

$Zn + 2OH^- \rightarrow ZnO + H_2O + 2e^-$

15 **Answer (B)**

The gaseous fuel used in rockets is H_2.

The fuel cell does not store the energy produced and needs a continuous supply of fuel.

16 **Answer (A)**

At the anode: $H_2 + 2OH^- \rightarrow 2H_2O + 2e^-$

At the cathode: $O_2 + 2H_2O + 4e^- \rightarrow 4OH^-$

So OH^- moves from the cathode towards the anode.

17 **Answer (A)**

The concentration of KOH stays constant because OH^- forms at the cathode at the same rate as it is used up at the anode.

18 **Answer (C)**

On discharging, the acid is used up, so its concentration and density decrease.

PbO_2 is reduced at the cathode $(+4 \text{ to } +2)$, and Pb is oxidized at the anode $(0 \text{ to } +2)$.

19 **Answer (D)**

$PbSO_4 \rightarrow Pb^{4+}$ is oxidation, so it takes place at the anode.

This reaction takes place on charging $(PbSO_4 \rightarrow PbO_2)$.

20 **Answer (C)**

On charging, the acid is formed, so its concentration increases.

$PbSO_4$ changes into Pb at the cathode and into PbO_2 at the anode.

21 **Answer (C)**

On charging, sulphuric acid is formed from $PbSO_4$ and water.

The mass of water decreases and H^+ increases, so the pH decreases and the pOH increases.

22 **Answer (C)**

On charging, the negative terminal of the source is connected to the lead electrode (the cathode).

The emf of the battery increases and the concentration of the acid increases.

23 **Answer (B)**

On charging, the acid is formed, so $[H^+]$ increases and the pH value decreases.

24 **Answer (D)**

Cell voltage = 0.36 + 1.69 = 2.05 V

A hydrometer reading of 1 g/cm³ shows that the acid is dilute, so it needs recharging.

One cell produces 2.05 V after charging, and the battery (6 cells) produces 12 V.

25 **Answer (A)**

On discharging, lithium ions move from the negative anode to the positive cathode.

26 **Answer (D)**

Zn is oxidized more easily than H_2 because it is higher in the activity series.

So it is the stronger reducing agent.

27 **Answer (C)**

In the mercury cell, the oxidation number of oxygen stays −2 (HgO, ZnO), so there is neither oxidation nor reduction.

In the fuel cell, what is reduced is the O_2 molecule, not oxygen ions.

28 **Answer (A)**

emf = 0.49 − (−0.88) = 1.37 V

A voltage greater than 1.37 V is needed to charge the battery.

29 **Model answer**

(1) (Y): the anode, (X): the cathode.

(2) The lead battery.