

APOLLO

Electron transfer reactions

HL

Chemistry

First assessment 2025

25 questions | questions

34. Ammonia, NH_3 and nitrous acid, HNO_2 , are compounds of nitrogen. What are the oxidation states of nitrogen in these compounds?

	NH_3	HNO_2
A.	+3	+3
B.	-3	-3
C.	+3	-3
D.	-3	+3

35. Below is a reactivity series of selected elements, arranged from highest activity to lowest.

Zn
Fe
Cd
Co
Ni
Sn
Pb
Cu

Which reaction is spontaneous?

- A. $\text{Cd}^{2+}(\text{aq}) + \text{Pb}(\text{s}) \rightarrow \text{Pb}^{2+}(\text{aq}) + \text{Cd}(\text{s})$
B. $\text{Fe}^{2+}(\text{aq}) + \text{Sn}(\text{s}) \rightarrow \text{Sn}^{2+}(\text{aq}) + \text{Fe}(\text{s})$
C. $\text{Zn}^{2+}(\text{aq}) + \text{Cu}(\text{s}) \rightarrow \text{Cu}^{2+}(\text{aq}) + \text{Zn}(\text{s})$
D. $\text{Ni}^{2+}(\text{aq}) + \text{Co}(\text{s}) \rightarrow \text{Co}^{2+}(\text{aq}) + \text{Ni}(\text{s})$

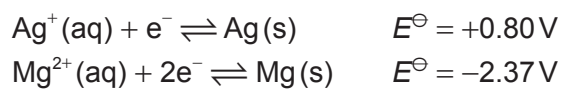
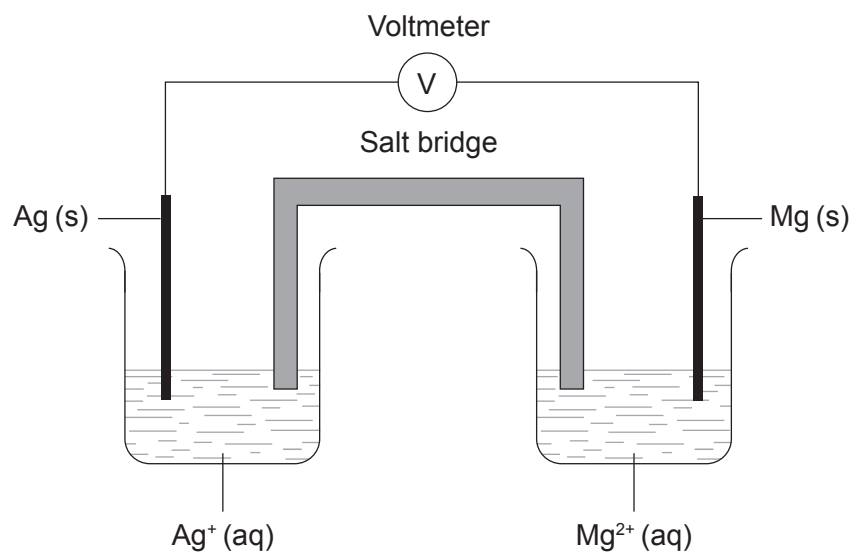
14. What is the oxidation state of nitrogen in N_2O_4 ?

- A. -4
- B. -2
- C. $+2$
- D. $+4$

36. In which compound does sulfur have an oxidation state of +4?

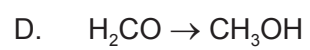
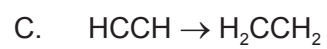
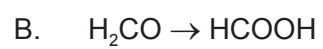
- A. H_2S
- B. SO_3
- C. H_2SO_3
- D. H_2SO_4

37. What is the standard cell potential, $E_{\text{cell}}^{\ominus}$, of the following cell?



- A. -3.17 V
- B. -1.57 V
- C. $+1.57 \text{ V}$
- D. $+3.17 \text{ V}$

38. Which change represents oxidation of the functional group?



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39. What are the products of the electrolysis of dilute aqueous copper(II) sulfate when using inert electrodes?

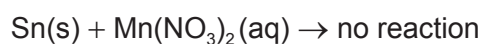
	Product at anode	Product at cathode
A.	oxygen gas	hydrogen gas
B.	oxygen gas	copper metal
C.	copper metal	oxygen gas
D.	hydrogen gas	copper metal

15. Which compounds contain an atom in a +3 oxidation state?



- A. I and II only
- B. I and III only
- C. II and III only
- D. I, II and III

36. The following occurs when tin is added to separate solutions of lead(II) nitrate, $\text{Pb}(\text{NO}_3)_2$, and manganese(II) nitrate, $\text{Mn}(\text{NO}_3)_2$.



What is the order of decreasing reactivity of the metals?

- A. $\text{Sn} > \text{Pb} > \text{Mn}$
- B. $\text{Sn} > \text{Mn} > \text{Pb}$
- C. $\text{Mn} > \text{Sn} > \text{Pb}$
- D. $\text{Pb} > \text{Sn} > \text{Mn}$

37. What are the products of the electrolysis of molten aluminium oxide, $\text{Al}_2\text{O}_3(\text{l})$?

	Product at anode	Product at cathode
A.	O_2	Al
B.	O_3	Al
C.	Al	O_2
D.	Al	O_3

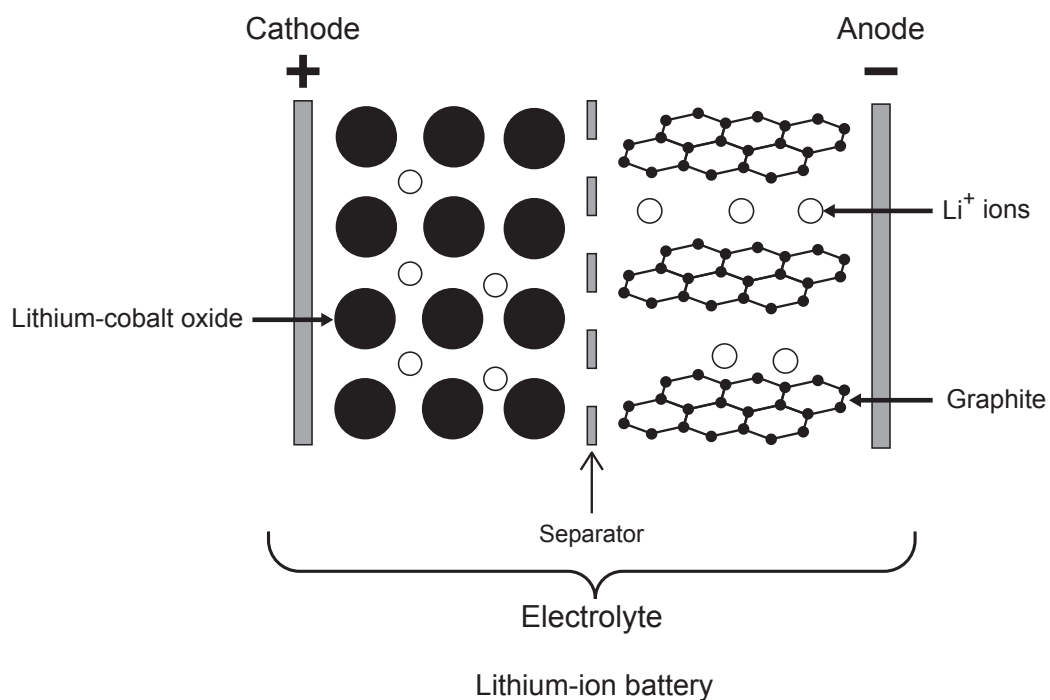
39. Consider the following standard electrode potentials:

	$E^{\ominus}(\text{V})$
$\text{Zn}^{2+}(\text{aq}) + 2\text{e}^{-} \rightleftharpoons \text{Zn}(\text{s})$	-0.76
$\text{Fe}^{2+}(\text{aq}) + 2\text{e}^{-} \rightleftharpoons \text{Fe}(\text{s})$	-0.45
$\text{Ni}^{2+}(\text{aq}) + 2\text{e}^{-} \rightleftharpoons \text{Ni}(\text{s})$	-0.26

Which species will react with each other spontaneously under standard conditions?

- A. Zn and Fe^{2+}
- B. Fe and Zn^{2+}
- C. Ni and Zn^{2+}
- D. Ni and Fe^{2+}

6. A lithium-ion battery consists of lithium ions on lithium-graphite (LiC_6) and lithium-cobalt oxide (LiCoO_2) in an electrolyte.



- (a) The lithium ions are produced at the anode from the lithium atoms embedded in graphite.

- (i) State a half-equation for the reaction occurring at the anode during discharge. [1]

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- (ii) Comment on the sign and value of the standard reduction potential of lithium that make it suitable to use in the battery. Use section 19 of the data booklet. [2]

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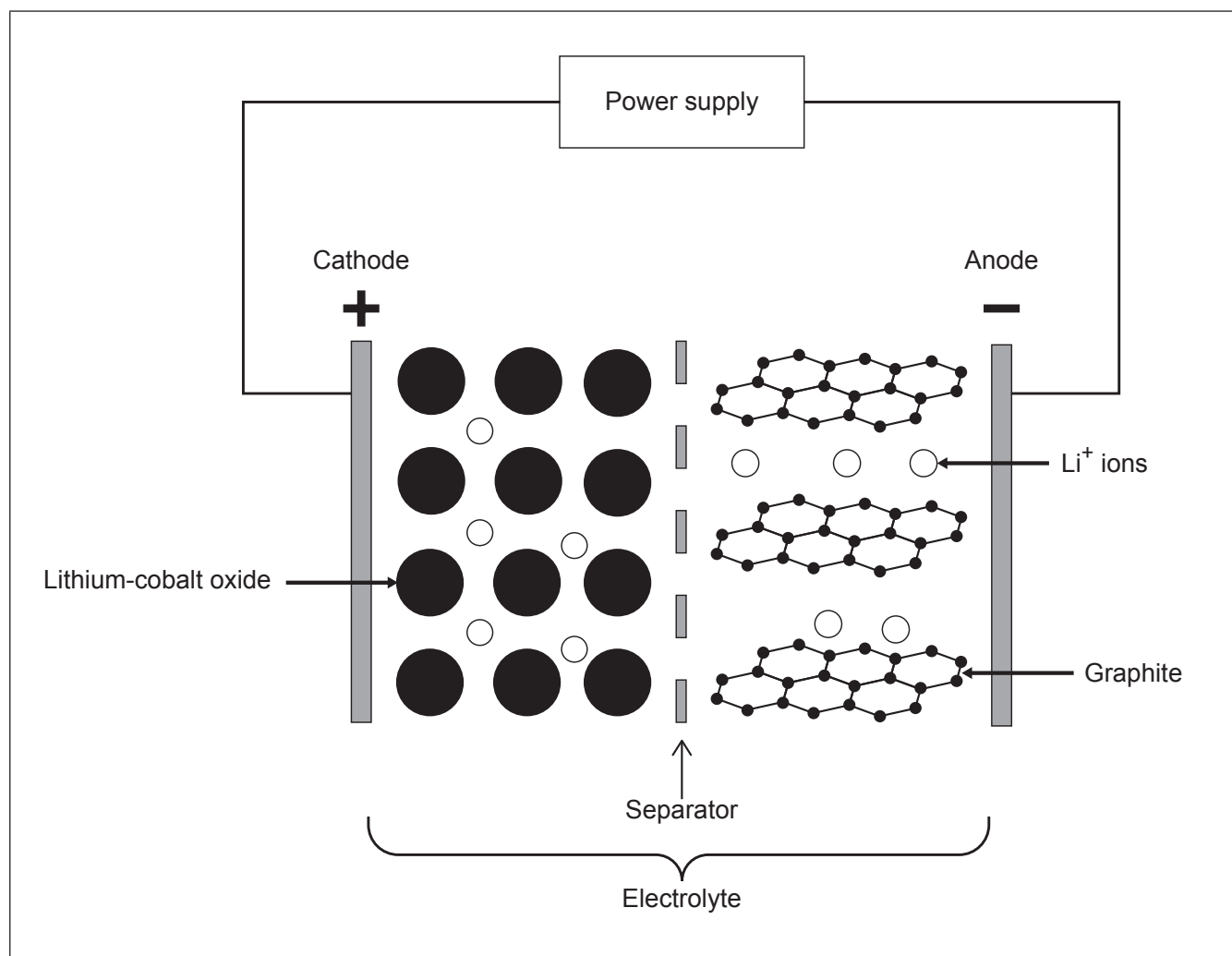
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(Question 6 continued)

- (b) The lithium-ion battery is rechargeable. Annotate the diagram below to show the direction of the flow of electrons in the wire while the battery is recharging. [1]



- (c) Suggest why solar panels are often connected in parallel with lithium-ion batteries. [1]

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(Question 6 continued)

- (d) A charge of 1000.0 C passes through a lithium-ion battery during discharge. Determine the number of lithium ions released at the anode. Use section 2 of the data booklet. [2]

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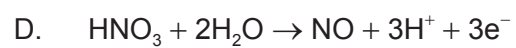
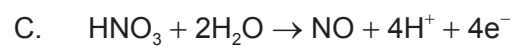
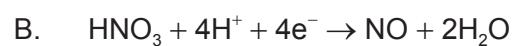
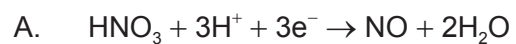
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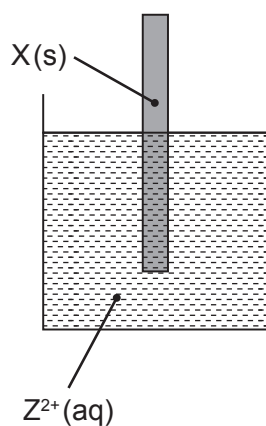
14. What are the oxidation states of the elements in Na_2CrO_4 ?

	Sodium	Chromium	Oxygen
A.	+1	+6	−1
B.	+2	+3	−1
C.	+1	+6	−2
D.	+2	+3	−2

34. What is the half equation for the reduction of nitric acid to nitrogen(II) oxide in acidic medium?

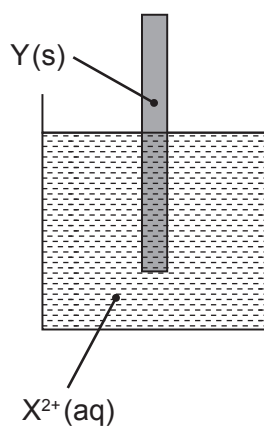


36. A student performed displacement reactions using metals X, Y, Z and solutions of their ions, X^{2+} , Y^{2+} , Z^{2+} . The results are shown.

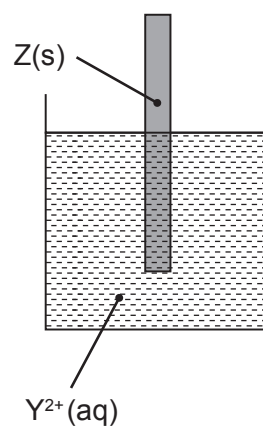


Results:

No reaction



No reaction

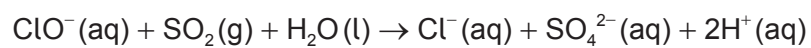


Reaction occurs

What is the increasing order of the reactivity of X, Y and Z metals?

- A. X, Y, Z
- B. Y, X, Z
- C. Z, X, Y
- D. Y, Z, X

33. What are the oxidizing and reducing agents in this reaction?



	Oxidizing agent	Reducing agent
A.	ClO^{-}	H_2O
B.	SO_2	SO_4^{2-}
C.	SO_2	ClO^{-}
D.	ClO^{-}	SO_2

34. Which statement about electrochemical cells is correct?

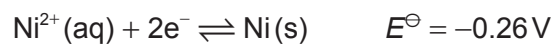
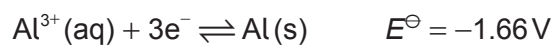
- A. Primary (voltaic) cells use electrical energy to produce a redox reaction.
- B. Electrolytic cells are rechargeable.
- C. Secondary cells can use electrical energy to produce a redox reaction.
- D. Primary (voltaic) cells are rechargeable.

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35. Consider two half-cells: $\text{Al(s)}/\text{Al}^{3+}(\text{aq})$ and $\text{Ni(s)}/\text{Ni}^{2+}(\text{aq})$.

What will be the cell potential, in V, when the two half-cells are connected?



- A. -2.54
- B. -1.40
- C. $+1.40$
- D. $+2.54$

- 36.** Which statement about the standard hydrogen electrode, SHE, is correct?
- A. The SHE must be the anode when measuring $E^\ominus$ values of another half-cell.
 - B. SHE has a standard reduction potential of 0 V at any temperature.
 - C. Cell potential is unaffected by the pressure of the hydrogen gas.
 - D. Any acid with a concentration of 1.0 mol dm^{-3} would give the same cell potential.

37. What are the main products when concentrated NaCl(aq) is electrolysed using inert electrodes?

	Anode	Cathode
A.	$\text{Cl}_2(\text{g})$	$\text{H}_2(\text{g})$
B.	$\text{O}_2(\text{g})$	$\text{H}_2(\text{g})$
C.	$\text{H}_2(\text{g})$	$\text{Cl}_2(\text{g})$
D.	$\text{H}_2(\text{g})$	$\text{O}_2(\text{g})$

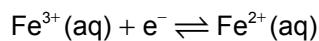
39. What is the oxidation state of Pt in $[\text{Pt}(\text{NH}_3)_5\text{Cl}]\text{Cl}_3$?

- A. +1
- B. +2
- C. +3
- D. +4

Section B

Answer **all** questions. Answers must be written within the answer boxes provided.

4. Half-cells such as



can be connected to other half-cells to form a voltaic cell.

- (a) Describe how you would connect the $\text{Fe}^{3+}|\text{Fe}^{2+}$ half-cell to another half-cell to compare their potentials. [2]

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- (b) The reduction potential, E , of the $\text{Fe}^{3+}|\text{Fe}^{2+}$ electrode varies with the concentration of the ions according to the equation:

$$E = 0.77 + \frac{RT}{F} \ln \left[\frac{\text{Fe}^{3+}}{\text{Fe}^{2+}} \right]$$

Determine the reduction potential at 25 °C, if $[\text{Fe}^{2+}] = 1.37 \times 10^{-2} \text{ mol dm}^{-3}$ and $[\text{Fe}^{3+}] = 3.25 \times 10^{-4} \text{ mol dm}^{-3}$.

Use section 2 of the data booklet. [3]

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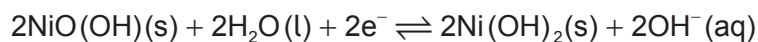
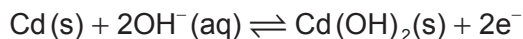
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5. Transition elements are known for having multiple oxidation states, forming coloured compounds and acting as catalysts. The existence of variable oxidation states means many are used in rechargeable batteries, also known as secondary cells.

- (a) (i) A common rechargeable battery is the nickel-cadmium, NiCd, battery where the two reactions during discharge are as follows.



Deduce the overall cell equation.

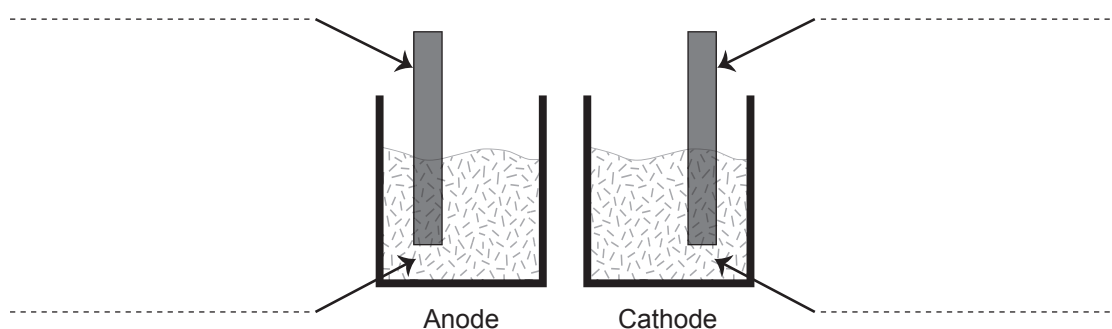
[1]

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- (ii) Simple cells rely on differences in standard electrode potential values between different elements and their ions. The following is an incomplete diagram for measuring a cell potential between $\text{Mn}^{2+}(\text{aq})/\text{Mn}$ and $\text{Ni}^{2+}(\text{aq})/\text{Ni}$ half-cells.

Draw the missing components and fully label the diagram to show how the cell potential can be measured.

[3]



- (iii) Calculate the standard cell potential, $E^\ominus_{\text{cell}}$, for this cell. Use section 19 of the data booklet.

[1]

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(Question 5 continued)

- (b) A different combination of half-cells produced a calculated value of Gibbs energy change, $\Delta G^\ominus$, of $-570.3 \text{ kJ mol}^{-1}$. The cell involved the transfer of one electron between the electrodes.

Deduce the half-cells involved in this battery. Use sections 1, 2 and 19 of the data booklet.

[3]

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- (c) Chromium, Cr, is a transition metal that produces a shiny surface and is used in the automobile industry. The chromium is deposited onto a base metal in an electrolytic cell.

Annotate the table, with ticks, ✓, to show the direction and place of movement of the species shown.

[2]

	Direction of movement		Place of movement	
Species	Towards cathode	Towards anode	In the wires	Through the electrolyte
Electrons				
Cr^{3+} ions				



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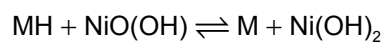
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- 34.** The overall reaction occurring at the electrodes of a rechargeable metal hydride battery can be summarized as:



Which statement is correct?

- A. The oxidation state of Ni does not change.
- B. M is oxidized by loss of hydrogen.
- C. The oxidation state of one H atom changes from -1 to $+1$.
- D. The oxidation state of one O atom changes from -1 to -2 .

35. In a redox titration, manganate(VII) ions are reduced to manganese(II) ions and iron(II) ions are oxidized to iron(III) ions.

$\text{MnO}_4^- (\text{aq})$ reduced to $\text{Mn}^{2+} (\text{aq})$

$\text{Fe}^{2+} (\text{aq})$ oxidized to $\text{Fe}^{3+} (\text{aq})$

What volume, in cm^3 , of $0.1 \text{ mol dm}^{-3} \text{ MnO}_4^- (\text{aq})$ is required to reach the equivalence point in the titration of 20.00 cm^3 of $0.1 \text{ mol dm}^{-3} \text{ Fe}^{2+} (\text{aq})$?

- A. 2.00
- B. 4.00
- C. 20.00
- D. 100.00