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STUDENT INSTRUCTIONS

1. Insert the stickers with your Personal Education Number (PEN) in the allotted spaces above. **Under no circumstance is your name or identification, other than your Personal Education Number, to appear on this booklet.**
2. Ensure that in addition to this examination booklet, you have a **Data Booklet** and an **Examination Response Form**. Follow the directions on the front of the Response Form.
3. **Disqualification** from the examination will result if you bring books, paper, notes or unauthorized electronic devices into the examination room.
4. When instructed to open this booklet, **check the numbering of the pages** to ensure that they are numbered in sequence from page one to the last page, which is identified by

END OF EXAMINATION.

5. At the end of the examination, place your Response Form inside the front cover of this booklet and return the booklet and your Response Form to the supervisor.

CHEMISTRY 12

JUNE 2000

COURSE CODE = CH

Insert **only** hand-printed PEN here.

Ministry use only.

Question 1:
1. .
(3)

Question 6:
6. .
(4)

Question 2:
2. .
(3)

Question 7:
7. .
(5)

Question 3:
3. .
(3)

Question 8:
8. .
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Question 4:
4. .
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Question 9:
9. .
(2)

Question 5:
5. .
(3)

Question 10:
10. .
(2)

CHEMISTRY 12

JUNE 2000

COURSE CODE = CH

GENERAL INSTRUCTIONS

1. Aside from an approved calculator, electronic devices, including dictionaries and pagers, are **not** permitted in the examination room.
2. All multiple-choice answers must be entered on the Response Form using an **HB pencil**. Multiple-choice answers entered in this examination booklet will **not** be marked.
3. For each of the written-response questions, write your answer in the space provided in this booklet.
4. Ensure that you use language and content appropriate to the purpose and audience of this examination. Failure to comply may result in your paper being awarded a zero.
5. This examination is designed to be completed in **two hours**. *Students may, however, take up to 30 minutes of additional time to finish.*

CHEMISTRY 12 PROVINCIAL EXAMINATION

	Value	Suggested Time
1. This examination consists of two parts:		
PART A: 48 multiple-choice questions	48	70
PART B: 10 written-response questions	32	50
	Total:	80 marks
		120 minutes

2. The following tables can be found in the separate **Data Booklet**.

- Periodic Table of the Elements
- Atomic Masses of the Elements
- Names, Formulae, and Charges of Some Common Ions
- Solubility of Common Compounds in Water
- Solubility Product Constants at 25°C
- Relative Strengths of Brønsted-Lowry Acids and Bases
- Acid-Base Indicators
- Standard Reduction Potentials of Half-cells

No other reference materials or tables are allowed.

3. **A calculator is essential for the Chemistry 12 Provincial Examination.** The calculator must be a hand-held device designed primarily for mathematical computations involving logarithmic and trigonometric functions and may also include graphing functions. Computers, calculators with a QWERTY keyboard, and electronic writing pads will not be allowed. Students must not bring any external devices to support calculators such as manuals, printed or electronic cards, printers, memory expansion chips or cards, or external keyboards. Students may have more than one calculator available during the examination. Calculators may not be shared and must not have the ability to either transmit or receive electronic signals. In addition to an approved calculator, students will be allowed to use rulers, compasses, and protractors during the examination.

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PART A: MULTIPLE CHOICE

Value: 48 marks

Suggested Time: 70 minutes

INSTRUCTIONS: For each question, select the **best** answer and record your choice on the Response Form provided. Using an HB pencil, completely fill in the circle that has the letter corresponding to your answer.

1. Which of the following reactions will be slowest at 25°C?

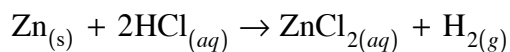
- A. $\text{Cu}_{(s)} + \text{S}_{(s)} \rightarrow \text{CuS}_{(s)}$
- B. $\text{H}^+_{(aq)} + \text{OH}^-_{(aq)} \rightarrow \text{H}_2\text{O}_{(\ell)}$
- C. $\text{Pb}^{2+}_{(aq)} + 2\text{Cl}^-_{(aq)} \rightarrow \text{PbCl}_{2(s)}$
- D. $2\text{NaOCl}_{(aq)} \rightarrow 2\text{NaCl}_{(aq)} + \text{O}_{2(g)}$

2. Which of the following could be used as the units for rate of a reaction?

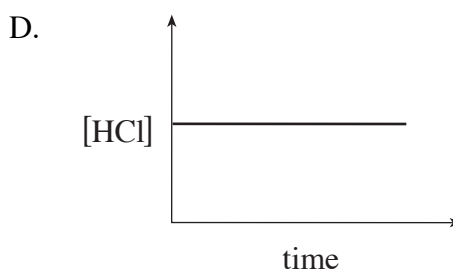
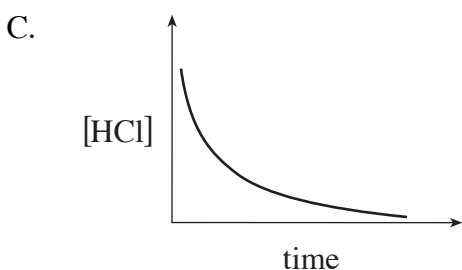
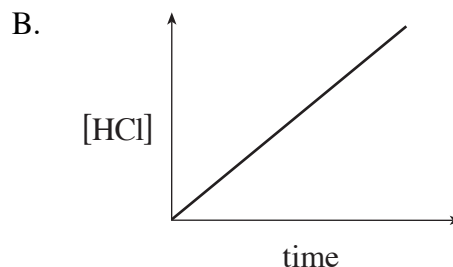
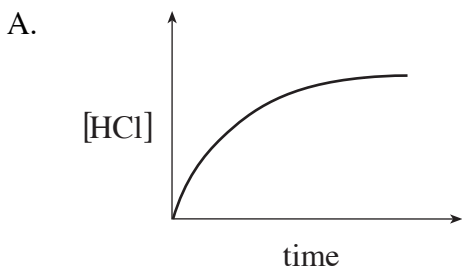
I.	mL/s
II.	g/min
III.	M/min

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

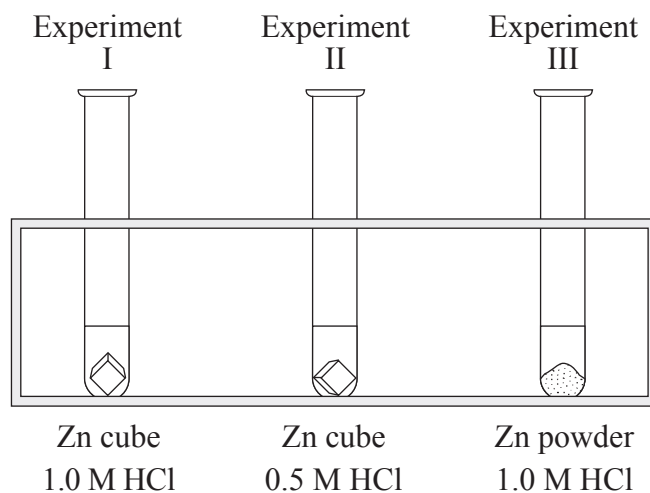
3. Consider the following reaction:



A graph of concentration of HCl vs time could be represented by



4. Consider the following experiments, each involving equal masses of zinc and 10.0 mL of acid:



The rate of reaction in order from fastest to slowest is

- A. I > II > III
- B. II > I > III
- C. III > I > II
- D. III > II > I

5. What happens to the energy of reactant molecules as they approach one another?

	Potential Energy	Kinetic Energy
A.	increases	increases
B.	increases	decreases
C.	decreases	increases
D.	decreases	decreases

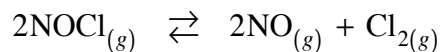
6. Consider the following reaction mechanism:

Step 1	$\text{ClO}^- + \text{H}_2\text{O} \rightarrow \text{HClO} + \text{OH}^-$
Step 2	$\text{I}^- + \text{HClO} \rightarrow \text{HIO} + \text{Cl}^-$
Step 3	$\text{HIO} + \text{OH}^- \rightarrow \text{IO}^- + \text{H}_2\text{O}$

The catalyst is

- A. IO^-
- B. H_2O
- C. ClO^-
- D. ClOH

7. Consider the following equilibrium:



A flask of fixed volume is initially filled with $\text{NOCl}_{(g)}$, $\text{NO}_{(g)}$ and $\text{Cl}_{2(g)}$. When equilibrium is reached, the pressure has increased. To reach equilibrium, the reaction proceeded to the

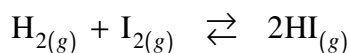
- A. left because Trial K_{eq} was less than K_{eq} .
- B. right because Trial K_{eq} was less than K_{eq} .
- C. left because Trial K_{eq} was greater than K_{eq} .
- D. right because Trial K_{eq} was greater than K_{eq} .

OVER

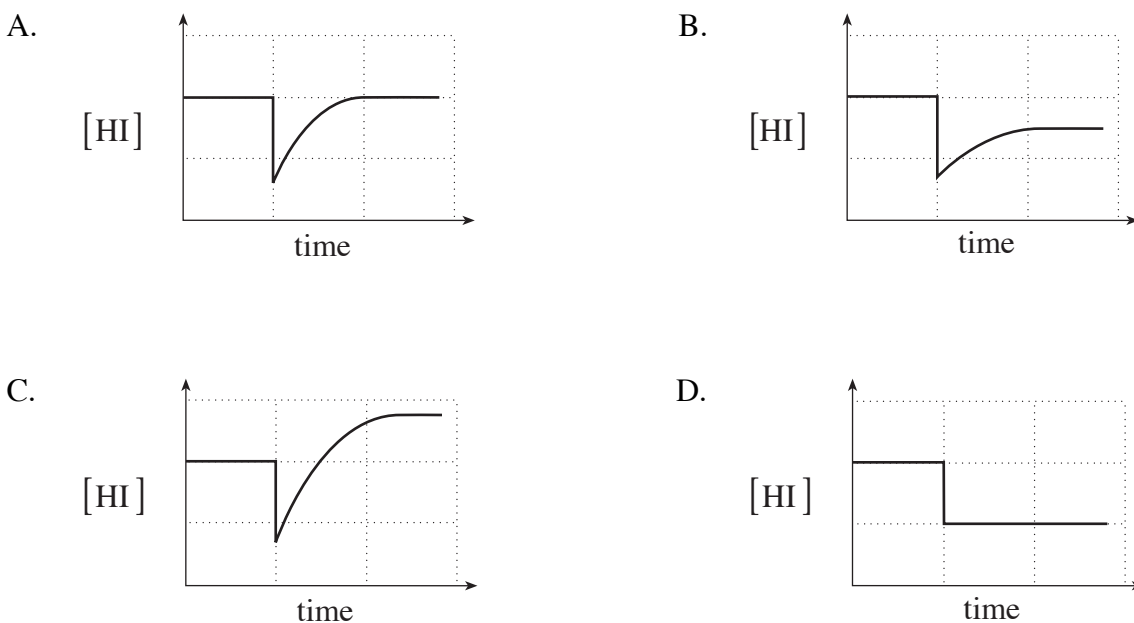
8. In which of the following do both minimum enthalpy and maximum entropy factors favour the reactants?

- A. $\text{Cl}_{2(g)} \rightleftharpoons \text{Cl}_{2(aq)}$ $\Delta H = -25 \text{ kJ}$
- B. $\text{C}_{(s)} + \text{H}_2\text{O}_{(\ell)} \rightleftharpoons \text{CO}_{(g)} + \text{H}_{2(g)}$ $\Delta H = +131 \text{ kJ}$
- C. $2\text{CO}_{2(g)} + 3\text{H}_2\text{O}_{(g)} \rightleftharpoons \text{C}_2\text{H}_5\text{OH}_{(\ell)} + 3\text{O}_{2(g)}$ $\Delta H = +1239 \text{ kJ}$
- D. $\text{Na}_2\text{CO}_{3(s)} + \text{HCl}_{(aq)} \rightleftharpoons 2\text{NaCl}_{(aq)} + \text{CO}_{2(g)} + \text{H}_2\text{O}_{(\ell)}$ $\Delta H = -28 \text{ kJ}$

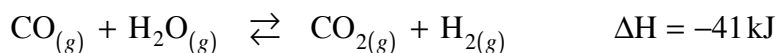
9. Consider the following equilibrium:



Which graph represents what happens when some HI is removed and a new equilibrium is established?



10. Consider the following equilibrium:



What will cause a shift in the equilibrium?

- A. adding a catalyst
- B. changing volume
- C. adding an inert gas
- D. changing temperature

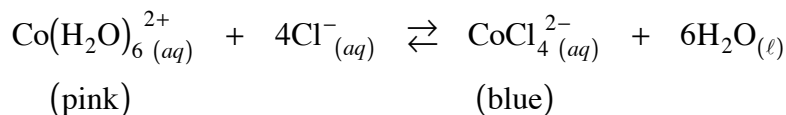
11. The equilibrium expression for a reaction is

$$K_{eq} = \frac{[H^+]^6}{[Bi^{3+}]^2 [H_2S]^3}$$

The reaction could be

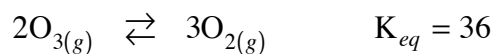
- A. $6H^+_{(aq)} + BiS_{(s)} \rightleftharpoons 2Bi^{3+}_{(aq)} + 3H_2S_{(g)}$
B. $6H^+_{(aq)} + Bi_2S_{3(s)} \rightleftharpoons 2Bi^{3+}_{(aq)} + 3H_2S_{(g)}$
C. $2Bi^{3+}_{(aq)} + 3H_2S_{(aq)} \rightleftharpoons Bi_2S_{3(s)} + 6H^+_{(aq)}$
D. $2Bi^{3+}_{(aq)} + 3H_2S_{(aq)} \rightleftharpoons Bi_2S_{3(aq)} + 6H^+_{(aq)}$

12. Consider the following equilibrium:



When the temperature is increased, the solution turns a dark blue. Based on this observation, the reaction is

- A. exothermic and the K_{eq} has increased.
B. exothermic and the K_{eq} has decreased.
C. endothermic and the K_{eq} has increased.
D. endothermic and the K_{eq} has decreased.
13. Consider the following equilibrium:



What is the concentration of O_3 when the equilibrium concentration of O_2 is 6.0×10^{-2} mol/L?

- A. 2.4×10^{-3} mol/L
B. 4.0×10^{-2} mol/L
C. 6.0×10^{-2} mol/L
D. 9.0×10^{-2} mol/L

OVER

14. A saturated solution of NaCl contains 36.5 g of solute in 0.100 L of solution. The solubility of the compound is
- A. 0.062 M
 - B. 1.60 M
 - C. 3.65 M
 - D. 6.24 M
15. Calculate the $[\text{Li}^+]$ in 200.0 mL of 1.5 M Li_2SO_4 .
- A. 0.30 M
 - B. 0.60 M
 - C. 1.5 M
 - D. 3.0 M
16. When equal volumes of 0.20 M RbCl and 0.20 M SrS are combined,
- A. no precipitate forms.
 - B. a precipitate of Rb_2S only forms.
 - C. a precipitate of SrCl_2 only forms.
 - D. precipitates of both Rb_2S and SrCl_2 form.
17. A solution contains both Ag^+ and Mg^{2+} ions. During selective precipitation, these ions are removed one at a time by adding
- A. I^- followed by OH^-
 - B. OH^- followed by S^{2-}
 - C. SO_4^{2-} followed by Cl^-
 - D. NO_3^- followed by PO_4^{3-}

18. The K_{sp} expression for a saturated solution of $Mg(OH)_2$ is

A. $K_{sp} = \frac{[Mg^{2+}][OH^-]^2}{[Mg(OH)_2]}$

B. $K_{sp} = [Mg^{2+}][OH^-]^2$

C. $K_{sp} = [Mg^{2+}][OH^-]$

D. $K_{sp} = [Mg^{2+}][2OH^-]^2$

19. Consider the following saturated solutions:



The order of cation concentration, from highest to lowest, is

A. $[Ba^{2+}] > [Ca^{2+}] > [Cu^{2+}]$

B. $[Ca^{2+}] > [Cu^{2+}] > [Ba^{2+}]$

C. $[Cu^{2+}] > [Ca^{2+}] > [Ba^{2+}]$

D. $[Cu^{2+}] > [Ba^{2+}] > [Ca^{2+}]$

20. When 1.0×10^{-3} moles of $CuCl_{2(s)}$ are added to 1.0 L of 1.0×10^{-3} M IO_3^- , the

A. Trial $K_{sp} > K_{sp}$ and a precipitate forms.

B. Trial $K_{sp} < K_{sp}$ and a precipitate forms.

C. Trial $K_{sp} > K_{sp}$ and no precipitate forms.

D. Trial $K_{sp} < K_{sp}$ and no precipitate forms.

21. The conjugate base of $H_2PO_4^-$ is

A. OH^-

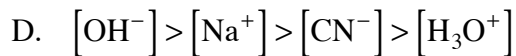
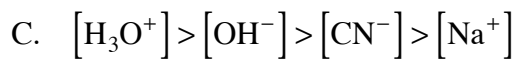
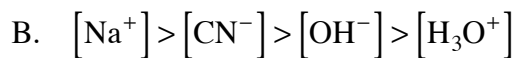
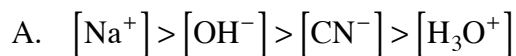
B. PO_4^{3-}

C. H_3PO_4

D. HPO_4^{2-}

22. Aqua regia is a concentrated aqueous solution of HCl and HNO₃. The strongest acid in aqua regia is
- A. HCl
 - B. H₂O
 - C. H₃O⁺
 - D. HNO₃
23. The predominant acid-base reaction between H₂O₂ and H₂O is
- A. $\text{H}_2\text{O}_2 + \text{H}_2\text{O} \rightarrow 3\text{OH}^- + \text{H}^+$
 - B. $\text{H}_2\text{O}_2 + \text{H}_2\text{O} \rightarrow 2\text{H}_2\text{O} + \text{O}^{2-}$
 - C. $\text{H}_2\text{O}_2 + \text{H}_2\text{O} \rightarrow \text{H}_3\text{O}_2^+ + \text{OH}^-$
 - D. $\text{H}_2\text{O}_2 + \text{H}_2\text{O} \rightarrow \text{H}_3\text{O}^+ + \text{HO}_2^-$
24. Which of the following reactions favours the formation of products?
- A. $\text{HNO}_2 + \text{F}^- \rightleftharpoons \text{HF} + \text{NO}_2^-$
 - B. $\text{H}_2\text{CO}_3 + \text{IO}_3^- \rightleftharpoons \text{HIO}_3 + \text{HCO}_3^-$
 - C. $\text{NH}_4^+ + \text{C}_2\text{O}_4^{2-} \rightleftharpoons \text{HC}_2\text{O}_4^- + \text{NH}_3$
 - D. $\text{HCN} + \text{HCOO}^- \rightleftharpoons \text{HCOOH} + \text{CN}^-$
25. Which of the following 1.0 M solutions will have the lowest [H₃O⁺] ?
- A. H₂S
 - B. HNO₂
 - C. H₂CO₃
 - D. CH₃COOH

26. In a solution of 0.10 M NaCN, the order of ion concentration, from highest to lowest, is



27. What will cause the value of K_w to change?

A. adding OH^-

B. adding a catalyst

C. decreasing the pH

D. increasing the temperature

28. What is the concentration of $\text{Sr}(\text{OH})_2$ in a solution with a pH = 11.00?

A. $2.0 \times 10^{-11} \text{ M}$

B. $1.0 \times 10^{-11} \text{ M}$

C. $5.0 \times 10^{-4} \text{ M}$

D. $1.0 \times 10^{-3} \text{ M}$

29. The K_a expression for HTe^- is

A. $K_a = \frac{[\text{H}_2\text{Te}][\text{OH}^-]}{[\text{HTe}^-]}$

B. $K_a = \frac{[\text{Te}^{2-}][\text{H}_3\text{O}^+]}{[\text{HTe}^-]}$

C. $K_a = \frac{[\text{HTe}^-][\text{H}_3\text{O}^+]}{[\text{H}_2\text{Te}]}$

D. $K_a = \frac{[\text{HTe}^-][\text{OH}^-]}{[\text{Te}^{2-}]}$

30. When comparing 1.0 M solutions of bases, the base with the lowest $[\text{OH}^-]$ is the
- A. weakest base and it has the largest K_b value.
 - B. strongest base and it has the largest K_b value.
 - C. weakest base and it has the smallest K_b value.
 - D. strongest base and it has the smallest K_b value.
31. The value of K_b for HC_2O_4^- is
- A. 1.7×10^{-13}
 - B. 1.6×10^{-10}
 - C. 6.4×10^{-5}
 - D. 5.9×10^{-2}
32. Which of the following applies at the transition point for all indicators, HInd?
- A. $[\text{HInd}] = [\text{Ind}^-]$
 - B. $[\text{Ind}^-] = [\text{H}_3\text{O}^+]$
 - C. $[\text{H}_3\text{O}^+] = [\text{OH}^-]$
 - D. $[\text{HInd}] = [\text{H}_3\text{O}^+]$
33. Identify the indicator that has a K_a of 1.6×10^{-7} ?
- A. methyl red
 - B. thymol blue
 - C. phenolphthalein
 - D. bromthymol blue

34. Which of the following acid solutions would require the smallest volume to completely neutralize 10.00 mL of 0.100 M NaOH ?

- A. 0.100 M HCl
- B. 0.100 M H_3PO_4
- C. 0.100 M $\text{H}_2\text{C}_2\text{O}_4$
- D. 0.100 M CH_3COOH

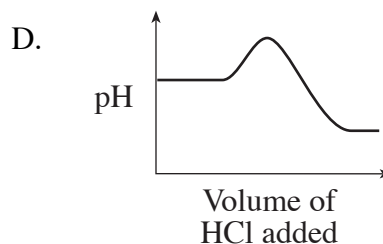
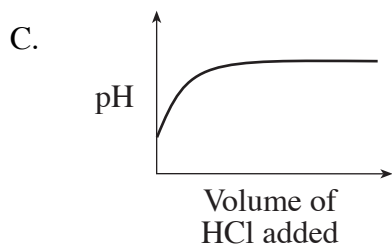
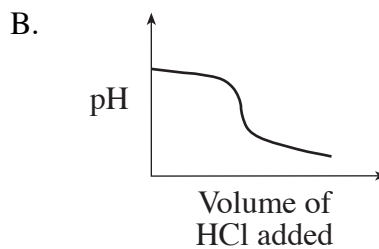
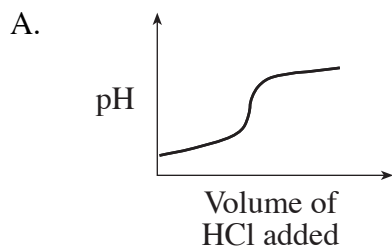
35. What is the pH of the solution formed when 0.040 mol $\text{NaOH}_{(s)}$ is added to 1.00 L of 0.050 M HCl ?

- A. 1.30
- B. 1.40
- C. 2.00
- D. 7.00

36. Which of the following titrations will have an equivalence point with a pH less than 7.00 ?

- A. H_2SO_4 with NH_3
- B. HNO_3 with LiOH
- C. H_3PO_4 with KOH
- D. HCOOH with NaOH

37. Which of the following graphs describes the relationship between pH of a buffer solution and a volume of HCl added to the buffer?



38. A substance that is reduced during a redox reaction

- A. loses mass.
- B. is the anode.
- C. is the reducing agent.
- D. is the oxidizing agent.

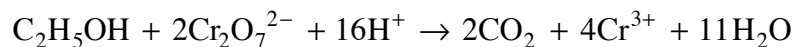
39. The oxidation number of As in $\text{H}_4\text{As}_2\text{O}_7$ is

- A. +4
- B. +5
- C. +9
- D. +10

40. In a reaction, the oxidation number of Cr decreases by 3. This indicates that Cr is

- A. reduced.
- B. oxidized.
- C. neutralized.
- D. a reducing agent.

41. Consider the following redox reaction:



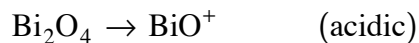
Each carbon atom loses

- A. 2 electrons
- B. 4 electrons
- C. 6 electrons
- D. 12 electrons

42. In which of the following 1.0 M solutions will both ions react spontaneously with tin?

- A. Ag^+ and Cu^{2+}
- B. Ni^{2+} and Cu^{2+}
- C. Zn^{2+} and Ni^{2+}
- D. Mg^{2+} and Zn^{2+}

43. Consider the following half-reaction:



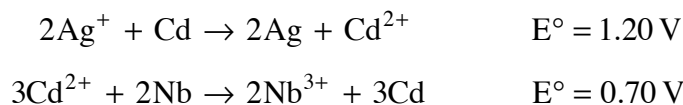
The balanced equation for this half-reaction is

- A. $\text{Bi}_2\text{O}_4 + 6\text{H}^+ + 5\text{e}^- \rightarrow \text{BiO}^+ + 3\text{H}_2\text{O}$
- B. $\text{Bi}_2\text{O}_4 + 8\text{H}^+ + 6\text{e}^- \rightarrow 2\text{BiO}^+ + 4\text{H}_2\text{O}$
- C. $\text{Bi}_2\text{O}_4 + 4\text{H}^+ + 2\text{e}^- \rightarrow 2\text{BiO}^+ + 2\text{H}_2\text{O}$
- D. $\text{Bi}_2\text{O}_4 + 4\text{H}^+ + 3\text{e}^- \rightarrow 2\text{BiO}^+ + 2\text{H}_2\text{O}$

44. To determine the concentration of $\text{Fe}^{2+}_{(aq)}$ by a redox titration, we could use an acidified standard solution of

- A. Sn^{2+}
- B. Pb^{2+}
- C. HCl
- D. H_2O_2

45. Consider the following redox reactions:

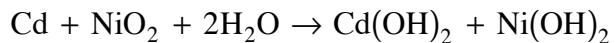


What is the E° for $\text{Nb}^{3+} + 3\text{e}^- \rightarrow \text{Nb}$?

- A. -1.90 V
- B. -1.10 V
- C. -0.50 V
- D. -0.40 V

OVER

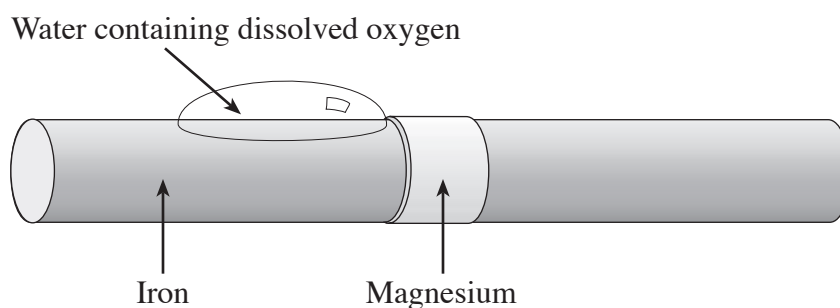
46. Consider the overall reaction for the rechargeable nickel-cadmium battery:



Which of the following occurs at the cathode as the reaction proceeds?

- A. Cd loses $2e^-$ and Cd(OH)_2 forms
- B. Cd gains $2e^-$ and Cd(OH)_2 forms
- C. NiO_2 loses $2e^-$ and Ni(OH)_2 forms
- D. NiO_2 gains $2e^-$ and Ni(OH)_2 forms

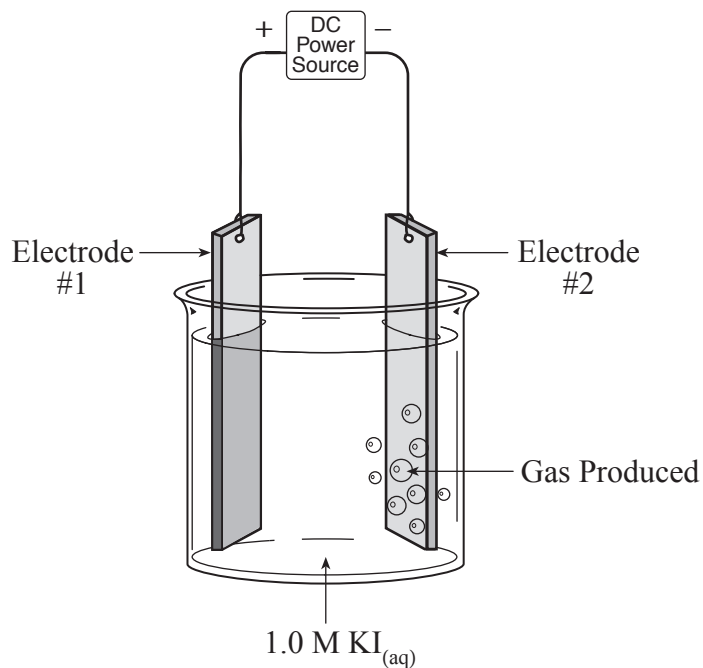
47. Consider the following diagram of a piece of iron, cathodically protected by magnesium:



What is happening during this process?

- A. Iron acts as the anode and water is oxidized.
- B. Iron acts as the cathode and oxygen is reduced.
- C. Magnesium acts as the anode and iron is oxidized.
- D. Magnesium acts as the cathode and iron is reduced.

48. Consider the following operating cell:



Which of the following describes the cell above?

	Electrode #1	Electrode #2	Gas Produced
A.	anode	cathode	H _{2(g)}
B.	anode	cathode	O _{2(g)}
C.	cathode	anode	H _{2(g)}
D.	cathode	anode	O _{2(g)}

**This is the end of the multiple-choice section.
Answer the remaining questions directly in this examination booklet.**

OVER

PART B: WRITTEN RESPONSE

Value: 32 marks

Suggested Time: 50 minutes

INSTRUCTIONS: You will be expected to communicate your knowledge and understanding of chemical principles in a clear and logical manner.

Your steps and assumptions leading to a solution must be written in the spaces below the questions.

Answers must include units where appropriate and be given to the correct number of significant figures.

For questions involving calculation, full marks will NOT be given for providing only an answer.

1. a) Complete the steps in the following mechanism. (1½ marks)

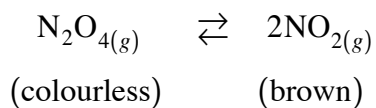
Step 1	$\text{NO} + \text{Pt} \rightarrow \underline{\hspace{2cm}}$
Step 2	$\text{NOPt} + \text{NO} \rightarrow \underline{\hspace{2cm}} + \underline{\hspace{2cm}}$
Step 3	$\text{O}_2\text{Pt} \rightarrow \text{O}_2 + \text{Pt}$
Overall	$2\text{NO} \rightarrow \text{N}_2 + \text{O}_2$

- b) Define the term *reaction intermediate* and give an example from the completed mechanism above. (1½ marks)

Definition: _____

Example: _____

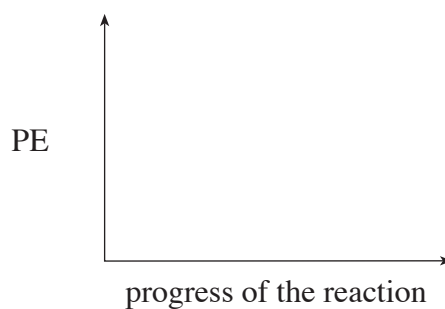
2. Consider the observations for the following equilibrium:



Trial	Temperature °C	Colour
I.	10	light brown
II.	50	dark brown

a) Sketch the potential energy curve on the graph below for this equilibrium.

(1 mark)

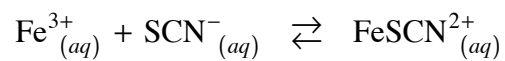


b) Explain the colour change using Le Châtelier's Principle.

(1 mark)

c) Other than changing temperature, what could be done to cause a shift to the left? **(1 mark)**

3. Consider the data obtained for the following equilibrium:



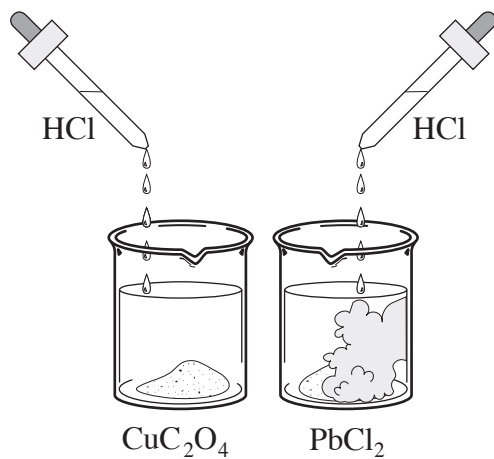
	$[\text{Fe}^{3+}]$	$[\text{SCN}^{-}]$	$[\text{FeSCN}^{2+}]$
Experiment 1	3.91×10^{-2}	8.02×10^{-5}	9.22×10^{-4}
Experiment 2	6.27×10^{-3}	3.65×10^{-4}	?

Calculate the $[\text{FeSCN}^{2+}]$ in experiment #2.

(3 marks)

4. At 25°C, will a precipitate form when 25.0 mL of 0.010 M $\text{Pb}(\text{NO}_3)_2$ is combined with 75.0 mL of 0.010 M NaI? Support your answer with calculations. **(3 marks)**

5. When HCl is added to a saturated solution of CuC_2O_4 , some precipitate dissolves. However, when HCl is added to a saturated solution of PbCl_2 , additional precipitate forms.



Explain these observations. Support your explanation with chemical equations. **(3 marks)**

6. A 0.100 M solution of an unknown weak acid, HX, has a $\text{pH} = 1.414$.
What is the K_a for HX?

(4 marks)

7. Consider the salt ammonium acetate, $\text{NH}_4\text{CH}_3\text{COO}$.

a) Write the equation for the dissociation of $\text{NH}_4\text{CH}_3\text{COO}$. **(1 mark)**

b) Write equations for the hydrolysis reactions which occur. **(2 marks)**

c) Explain why a solution of $\text{NH}_4\text{CH}_3\text{COO}$ has a $\text{pH} = 7.00$.
Support your answer with calculations. **(2 marks)**

8. The metals Rh, Ti, Cr and Pd are individually placed in 1.0 M solutions of Rh^{2+} , Ti^{2+} , Cr^{2+} and Pd^{2+} and the cell voltages of the spontaneous reactions are determined.

ION METAL	Rh^{2+}	Ti^{2+}	Pd^{2+}	Cr^{2+}
Rh		no reaction	0.35 V	no reaction
Ti	2.23 V		2.58 V	?
Pd	no reaction	no reaction		no reaction
Cr	1.51 V	no reaction	1.86 V	

- a) Arrange the metals in order of **increasing** strength as reducing agents. **(2 marks)**

weakest reducing agent _____, _____, _____, _____ strongest reducing agent

- b) Determine the cell voltage for Ti in a 1.0 M solution of Cr^{2+} . **(2 marks)**

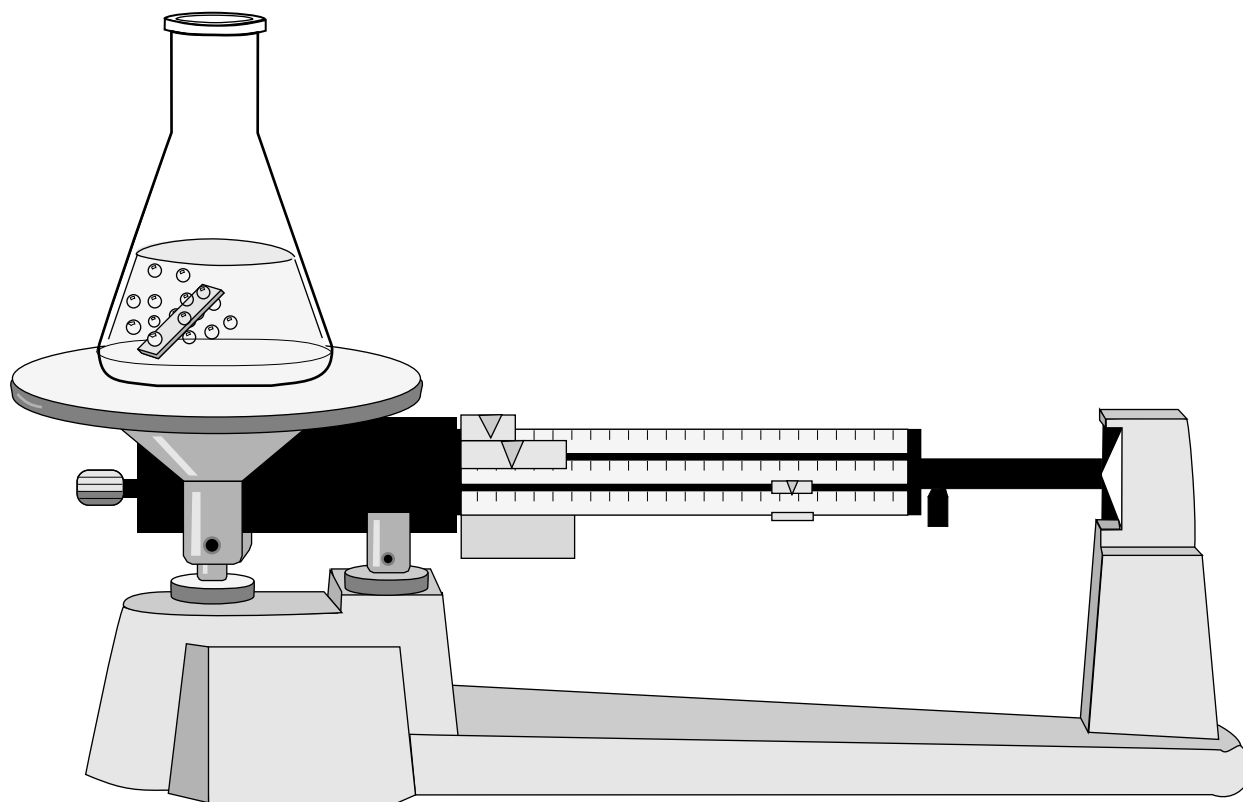
10. Draw and label an electrochemical cell using a copper anode and having an E° value > 1.00 V.
(2 marks)

END OF EXAMINATION

Data Booklet

CHEMISTRY 12

Work done in this booklet
will not be marked.



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7	Acid-base Indicators
8	Standard Reduction Potentials of Half-cells

REFERENCE

D.R. Lide, *CRC Handbook of Chemistry and Physics*, 80th edition, CRC Press, Boca Raton, 1999.

ATOMIC MASSES OF THE ELEMENTS

*Based on mass of C¹² at 12.00.
Values in parentheses are the mass number of the most stable or best
known isotopes for elements that do not occur naturally.*

Element	Symbol	Atomic Number	Atomic Mass	Element	Symbol	Atomic Number	Atomic Mass
Actinium	Ac	89	(227)	Mercury	Hg	80	200.6
Aluminum	Al	13	27.0	Molybdenum	Mo	42	95.9
Americium	Am	95	(243)	Neodymium	Nd	60	144.2
Antimony	Sb	51	121.8	Neon	Ne	10	20.2
Argon	Ar	18	39.9	Neptunium	Np	93	(237)
Arsenic	As	33	74.9	Nickel	Ni	28	58.7
Astatine	At	85	(210)	Niobium	Nb	41	92.9
Barium	Ba	56	137.3	Nitrogen	N	7	14.0
Berkelium	Bk	97	(247)	Nobelium	No	102	(259)
Beryllium	Be	4	9.0	Osmium	Os	76	190.2
Bismuth	Bi	83	209.0	Oxygen	O	8	16.0
Boron	B	5	10.8	Palladium	Pd	46	106.4
Bromine	Br	35	79.9	Phosphorus	P	15	31.0
Cadmium	Cd	48	112.4	Platinum	Pt	78	195.1
Calcium	Ca	20	40.1	Plutonium	Pu	94	(244)
Californium	Cf	98	(251)	Polonium	Po	84	(209)
Carbon	C	6	12.0	Potassium	K	19	39.1
Cerium	Ce	58	140.1	Praseodymium	Pr	59	140.9
Cesium	Cs	55	132.9	Promethium	Pm	61	(145)
Chlorine	Cl	17	35.5	Protactinium	Pa	91	231.0
Chromium	Cr	24	52.0	Radium	Ra	88	(226)
Cobalt	Co	27	58.9	Radon	Rn	86	(222)
Copper	Cu	29	63.5	Rhenium	Re	75	186.2
Curium	Cm	96	(247)	Rhodium	Rh	45	102.9
Dubnium	Db	105	(262)	Rubidium	Rb	37	85.5
Dysprosium	Dy	66	162.5	Ruthenium	Ru	44	101.1
Einsteinium	Es	99	(252)	Rutherfordium	Rf	104	(261)
Erbium	Er	68	167.3	Samarium	Sm	62	150.4
Europium	Eu	63	152.0	Scandium	Sc	21	45.0
Fermium	Fm	100	(257)	Selenium	Se	34	79.0
Fluorine	F	9	19.0	Silicon	Si	14	28.1
Francium	Fr	87	(223)	Silver	Ag	47	107.9
Gadolinium	Gd	64	157.3	Sodium	Na	11	23.0
Gallium	Ga	31	69.7	Strontium	Sr	38	87.6
Germanium	Ge	32	72.6	Sulphur	S	16	32.1
Gold	Au	79	197.0	Tantalum	Ta	73	180.9
Hafnium	Hf	72	178.5	Technetium	Tc	43	(98)
Helium	He	2	4.0	Tellurium	Te	52	127.6
Holmium	Ho	67	164.9	Terbium	Tb	65	158.9
Hydrogen	H	1	1.0	Thallium	Tl	81	204.4
Indium	In	49	114.8	Thorium	Th	90	232.0
Iodine	I	53	126.9	Thulium	Tm	69	168.9
Iridium	Ir	77	192.2	Tin	Sn	50	118.7
Iron	Fe	26	55.8	Titanium	Ti	22	47.9
Krypton	Kr	36	83.8	Tungsten	W	74	183.8
Lanthanum	La	57	138.9	Uranium	U	92	238.0
Lawrencium	Lr	103	(262)	Vanadium	V	23	50.9
Lead	Pb	82	207.2	Xenon	Xe	54	131.3
Lithium	Li	3	6.9	Ytterbium	Yb	70	173.0
Lutetium	Lu	71	175.0	Yttrium	Y	39	88.9
Magnesium	Mg	12	24.3	Zinc	Zn	30	65.4
Manganese	Mn	25	54.9	Zirconium	Zr	40	91.2
Mendelevium	Md	101	(258)				

NAMES, FORMULAE, AND CHARGES OF SOME COMMON IONS

* *Aqueous solutions are readily oxidized by air.*

** *Not stable in aqueous solutions.*

Positive Ions (Cations)			
Al^{3+}	Aluminum	Pb^{4+}	Lead(IV), plumbic
NH_4^+	Ammonium	Li^+	Lithium
Ba^{2+}	Barium	Mg^{2+}	Magnesium
Ca^{2+}	Calcium	Mn^{2+}	Manganese(II), manganous
Cr^{2+}	Chromium(II), chromous	Mn^{4+}	Manganese(IV)
Cr^{3+}	Chromium(III), chromic	Hg_2^{2+}	Mercury(I)*, mercurous
Cu^+	Copper(I)*, cuprous	Hg^{2+}	Mercury(II), mercuric
Cu^{2+}	Copper(II), cupric	K^+	Potassium
H^+	Hydrogen	Ag^+	Silver
H_3O^+	Hydronium	Na^+	Sodium
Fe^{2+}	Iron(II)*, ferrous	Sn^{2+}	Tin(II)*, stannous
Fe^{3+}	Iron(III), ferric	Sn^{4+}	Tin(IV), stannic
Pb^{2+}	Lead(II), plumbous	Zn^{2+}	Zinc

Negative Ions (Anions)			
Br^-	Bromide	OH^-	Hydroxide
CO_3^{2-}	Carbonate	ClO^-	Hypochlorite
ClO_3^-	Chlorate	I^-	Iodide
Cl^-	Chloride	HPO_4^{2-}	Monohydrogen phosphate
ClO_2^-	Chlorite	NO_3^-	Nitrate
CrO_4^{2-}	Chromate	NO_2^-	Nitrite
CN^-	Cyanide	$\text{C}_2\text{O}_4^{2-}$	Oxalate
$\text{Cr}_2\text{O}_7^{2-}$	Dichromate	O^{2-}	Oxide**
H_2PO_4^-	Dihydrogen phosphate	ClO_4^-	Perchlorate
CH_3COO^-	Ethanoate, acetate	MnO_4^-	Permanganate
F^-	Fluoride	PO_4^{3-}	Phosphate
HCO_3^-	Hydrogen carbonate, bicarbonate	SO_4^{2-}	Sulphate
HC_2O_4^-	Hydrogen oxalate, binoxalate	S^{2-}	Sulphide
HSO_4^-	Hydrogen sulphate, bisulphate	SO_3^{2-}	Sulphite
HS^-	Hydrogen sulphide, bisulphide	SCN^-	Thiocyanate
HSO_3^-	Hydrogen sulphite, bisulphite		

SOLUBILITY OF COMMON COMPOUNDS IN WATER

The term soluble here means > 0.1 mol/L at 25°C.

Negative Ions (Anions)	Positive Ions (Cations)	Solubility of Compounds
All	Alkali ions: Li ⁺ , Na ⁺ , K ⁺ , Rb ⁺ , Cs ⁺ , Fr ⁺	Soluble
All	Hydrogen ion: H ⁺	Soluble
All	Ammonium ion: NH ₄ ⁺	Soluble
Nitrate, NO ₃ ⁻	All	Soluble
Chloride, Cl ⁻ or Bromide, Br ⁻ or Iodide, I ⁻	All others	Soluble
	Ag ⁺ , Pb ²⁺ , Cu ⁺	Low Solubility
Sulphate, SO ₄ ²⁻	All others	Soluble
	Ag ⁺ , Ca ²⁺ , Sr ²⁺ , Ba ²⁺ , Pb ²⁺	Low Solubility
Sulphide, S ²⁻	Alkali ions, H ⁺ , NH ₄ ⁺ , Be ²⁺ , Mg ²⁺ , Ca ²⁺ , Sr ²⁺ , Ba ²⁺	Soluble
	All others	Low Solubility
Hydroxide, OH ⁻	Alkali ions, H ⁺ , NH ₄ ⁺ , Sr ²⁺	Soluble
	All others	Low Solubility
Phosphate, PO ₄ ³⁻ or Carbonate, CO ₃ ²⁻ or Sulphite, SO ₃ ²⁻	Alkali ions, H ⁺ , NH ₄ ⁺	Soluble
	All others	Low Solubility

SOLUBILITY PRODUCT CONSTANTS AT 25°C

Name	Formula	K_{sp}
Barium carbonate	BaCO ₃	2.6×10^{-9}
Barium chromate	BaCrO ₄	1.2×10^{-10}
Barium sulphate	BaSO ₄	1.1×10^{-10}
Calcium carbonate	CaCO ₃	5.0×10^{-9}
Calcium oxalate	CaC ₂ O ₄	2.3×10^{-9}
Calcium sulphate	CaSO ₄	7.1×10^{-5}
Copper(I) iodide	CuI	1.3×10^{-12}
Copper(II) iodate	Cu(IO ₃) ₂	6.9×10^{-8}
Copper(II) sulphide	CuS	6.0×10^{-37}
Iron(II) hydroxide	Fe(OH) ₂	4.9×10^{-17}
Iron(II) sulphide	FeS	6.0×10^{-19}
Iron(III) hydroxide	Fe(OH) ₃	2.6×10^{-39}
Lead(II) bromide	PbBr ₂	6.6×10^{-6}
Lead(II) chloride	PbCl ₂	1.2×10^{-5}
Lead(II) iodate	Pb(IO ₃) ₂	3.7×10^{-13}
Lead(II) iodide	PbI ₂	8.5×10^{-9}
Lead(II) sulphate	PbSO ₄	1.8×10^{-8}
Magnesium carbonate	MgCO ₃	6.8×10^{-6}
Magnesium hydroxide	Mg(OH) ₂	5.6×10^{-12}
Silver bromate	AgBrO ₃	5.3×10^{-5}
Silver bromide	AgBr	5.4×10^{-13}
Silver carbonate	Ag ₂ CO ₃	8.5×10^{-12}
Silver chloride	AgCl	1.8×10^{-10}
Silver chromate	Ag ₂ CrO ₄	1.1×10^{-12}
Silver iodate	AgIO ₃	3.2×10^{-8}
Silver iodide	AgI	8.5×10^{-17}
Strontium carbonate	SrCO ₃	5.6×10^{-10}
Strontium fluoride	SrF ₂	4.3×10^{-9}
Strontium sulphate	SrSO ₄	3.4×10^{-7}
Zinc sulphide	ZnS	2.0×10^{-25}

RELATIVE STRENGTHS OF BRØNSTED-LOWRY ACIDS AND BASES
in aqueous solution at room temperature.

Name of Acid	Acid	Base	K_a
Perchloric	HClO_4	$\rightarrow \text{H}^+ + \text{ClO}_4^-$	very large
Hydriodic	HI	$\rightarrow \text{H}^+ + \text{I}^-$	very large
Hydrobromic	HBr	$\rightarrow \text{H}^+ + \text{Br}^-$	very large
Hydrochloric	HCl	$\rightarrow \text{H}^+ + \text{Cl}^-$	very large
Nitric	HNO_3	$\rightarrow \text{H}^+ + \text{NO}_3^-$	very large
Sulphuric	H_2SO_4	$\rightarrow \text{H}^+ + \text{HSO}_4^-$	very large
Hydronium Ion	H_3O^+	$\rightleftharpoons \text{H}^+ + \text{H}_2\text{O}$	1.0
Iodic	HIO_3	$\rightleftharpoons \text{H}^+ + \text{IO}_3^-$	1.7×10^{-1}
Oxalic	$\text{H}_2\text{C}_2\text{O}_4$	$\rightleftharpoons \text{H}^+ + \text{HC}_2\text{O}_4^-$	5.9×10^{-2}
Sulphurous ($\text{SO}_2 + \text{H}_2\text{O}$)	H_2SO_3	$\rightleftharpoons \text{H}^+ + \text{HSO}_3^-$	1.5×10^{-2}
Hydrogen sulphate ion	HSO_4^-	$\rightleftharpoons \text{H}^+ + \text{SO}_4^{2-}$	1.2×10^{-2}
Phosphoric	H_3PO_4	$\rightleftharpoons \text{H}^+ + \text{H}_2\text{PO}_4^-$	7.5×10^{-3}
Hexaaquoiron ion, iron(III) ion	$\text{Fe}(\text{H}_2\text{O})_6^{3+}$	$\rightleftharpoons \text{H}^+ + \text{Fe}(\text{H}_2\text{O})_5(\text{OH})^{2+}$	6.0×10^{-3}
Citric	$\text{H}_3\text{C}_6\text{H}_5\text{O}_7$	$\rightleftharpoons \text{H}^+ + \text{H}_2\text{C}_6\text{H}_5\text{O}_7^-$	7.1×10^{-4}
Nitrous	HNO_2	$\rightleftharpoons \text{H}^+ + \text{NO}_2^-$	4.6×10^{-4}
Hydrofluoric	HF	$\rightleftharpoons \text{H}^+ + \text{F}^-$	3.5×10^{-4}
Methanoic, formic	HCOOH	$\rightleftharpoons \text{H}^+ + \text{HCOO}^-$	1.8×10^{-4}
Hexaaquochromium ion, chromium(III) ion	$\text{Cr}(\text{H}_2\text{O})_6^{3+}$	$\rightleftharpoons \text{H}^+ + \text{Cr}(\text{H}_2\text{O})_5(\text{OH})^{2+}$	1.5×10^{-4}
Benzoic	$\text{C}_6\text{H}_5\text{COOH}$	$\rightleftharpoons \text{H}^+ + \text{C}_6\text{H}_5\text{COO}^-$	6.5×10^{-5}
Hydrogen oxalate ion	HC_2O_4^-	$\rightleftharpoons \text{H}^+ + \text{C}_2\text{O}_4^{2-}$	6.4×10^{-5}
Ethanoic, acetic	CH_3COOH	$\rightleftharpoons \text{H}^+ + \text{CH}_3\text{COO}^-$	1.8×10^{-5}
Dihydrogen citrate ion	$\text{H}_2\text{C}_6\text{H}_5\text{O}_7^-$	$\rightleftharpoons \text{H}^+ + \text{HC}_6\text{H}_5\text{O}_7^{2-}$	1.7×10^{-5}
Hexaaquoaluminum ion, aluminum ion	$\text{Al}(\text{H}_2\text{O})_6^{3+}$	$\rightleftharpoons \text{H}^+ + \text{Al}(\text{H}_2\text{O})_5(\text{OH})^{2+}$	1.4×10^{-5}
Carbonic ($\text{CO}_2 + \text{H}_2\text{O}$)	H_2CO_3	$\rightleftharpoons \text{H}^+ + \text{HCO}_3^-$	4.3×10^{-7}
Monohydrogen citrate ion	$\text{HC}_6\text{H}_5\text{O}_7^{2-}$	$\rightleftharpoons \text{H}^+ + \text{C}_6\text{H}_5\text{O}_7^{3-}$	4.1×10^{-7}
Hydrogen sulphite ion	HSO_3^-	$\rightleftharpoons \text{H}^+ + \text{SO}_3^{2-}$	1.0×10^{-7}
Hydrogen sulphide	H_2S	$\rightleftharpoons \text{H}^+ + \text{HS}^-$	9.1×10^{-8}
Dihydrogen phosphate ion	H_2PO_4^-	$\rightleftharpoons \text{H}^+ + \text{HPO}_4^{2-}$	6.2×10^{-8}
Boric	H_3BO_3	$\rightleftharpoons \text{H}^+ + \text{H}_2\text{BO}_3^-$	7.3×10^{-10}
Ammonium ion	NH_4^+	$\rightleftharpoons \text{H}^+ + \text{NH}_3$	5.6×10^{-10}
Hydrocyanic	HCN	$\rightleftharpoons \text{H}^+ + \text{CN}^-$	4.9×10^{-10}
Phenol	$\text{C}_6\text{H}_5\text{OH}$	$\rightleftharpoons \text{H}^+ + \text{C}_6\text{H}_5\text{O}^-$	1.3×10^{-10}
Hydrogen carbonate ion	HCO_3^-	$\rightleftharpoons \text{H}^+ + \text{CO}_3^{2-}$	5.6×10^{-11}
Hydrogen peroxide	H_2O_2	$\rightleftharpoons \text{H}^+ + \text{HO}_2^-$	2.4×10^{-12}
Monohydrogen phosphate ion	HPO_4^{2-}	$\rightleftharpoons \text{H}^+ + \text{PO}_4^{3-}$	2.2×10^{-13}
Water	H_2O	$\rightleftharpoons \text{H}^+ + \text{OH}^-$	1.0×10^{-14}
Hydroxide ion	OH^-	$\leftarrow \text{H}^+ + \text{O}^{2-}$	very small
Ammonia	NH_3	$\leftarrow \text{H}^+ + \text{NH}_2^-$	very small

ACID-BASE INDICATORS

Indicator	pH Range in Which Colour Change Occurs	Colour Change as pH Increases
Methyl violet	0.0 – 1.6	yellow to blue
Thymol blue	1.2 – 2.8	red to yellow
Orange IV	1.4 – 2.8	red to yellow
Methyl orange	3.2 – 4.4	red to yellow
Bromcresol green	3.8 – 5.4	yellow to blue
Methyl red	4.8 – 6.0	red to yellow
Chlorophenol red	5.2 – 6.8	yellow to red
Bromthymol blue	6.0 – 7.6	yellow to blue
Phenol red	6.6 – 8.0	yellow to red
Neutral red	6.8 – 8.0	red to amber
Thymol blue	8.0 – 9.6	yellow to blue
Phenolphthalein	8.2 – 10.0	colourless to pink
Thymolphthalein	9.4 – 10.6	colourless to blue
Alizarin yellow	10.1 – 12.0	yellow to red
Indigo carmine	11.4 – 13.0	blue to yellow

STANDARD REDUCTION POTENTIALS OF HALF-CELLS

Ionic concentrations are at 1M in water at 25°C.

	Oxidizing Agents	Reducing Agents	E° (Volts)	
STRONG		$F_{2(g)} + 2e^- \rightleftharpoons 2F^-$	+2.87	WEAK
		$S_2O_8^{2-} + 2e^- \rightleftharpoons 2SO_4^{2-}$	+2.01	
		$H_2O_2 + 2H^+ + 2e^- \rightleftharpoons 2H_2O$	+1.78	
		$MnO_4^- + 8H^+ + 5e^- \rightleftharpoons Mn^{2+} + 4H_2O$	+1.51	
		$Au^{3+} + 3e^- \rightleftharpoons Au_{(s)}$	+1.50	
		$BrO_3^- + 6H^+ + 5e^- \rightleftharpoons \frac{1}{2}Br_{2(l)} + 3H_2O$	+1.48	
		$ClO_4^- + 8H^+ + 8e^- \rightleftharpoons Cl^- + 4H_2O$	+1.39	
		$Cl_{2(g)} + 2e^- \rightleftharpoons 2Cl^-$	+1.36	
		$Cr_2O_7^{2-} + 14H^+ + 6e^- \rightleftharpoons 2Cr^{3+} + 7H_2O$	+1.23	
		$\frac{1}{2}O_{2(g)} + 2H^+ + 2e^- \rightleftharpoons H_2O$	+1.23	
		$MnO_{2(s)} + 4H^+ + 2e^- \rightleftharpoons Mn^{2+} + 2H_2O$	+1.22	
		$IO_3^- + 6H^+ + 5e^- \rightleftharpoons \frac{1}{2}I_{2(s)} + 3H_2O$	+1.20	
		$Br_{2(l)} + 2e^- \rightleftharpoons 2Br^-$	+1.09	
		$AuCl_4^- + 3e^- \rightleftharpoons Au_{(s)} + 4Cl^-$	+1.00	
		$NO_3^- + 4H^+ + 3e^- \rightleftharpoons NO_{(g)} + 2H_2O$	+0.96	
		$Hg^{2+} + 2e^- \rightleftharpoons Hg_{(l)}$	+0.85	
		$\frac{1}{2}O_{2(g)} + 2H^+(10^{-7}M) + 2e^- \rightleftharpoons H_2O$	+0.82	
		$2NO_3^- + 4H^+ + 2e^- \rightleftharpoons N_2O_4 + 2H_2O$	+0.80	
		$Ag^+ + e^- \rightleftharpoons Ag_{(s)}$	+0.80	
		$\frac{1}{2}Hg_2^{2+} + e^- \rightleftharpoons Hg_{(l)}$	+0.80	
		$Fe^{3+} + e^- \rightleftharpoons Fe^{2+}$	+0.77	
		$O_{2(g)} + 2H^+ + 2e^- \rightleftharpoons H_2O_2$	+0.70	
		$MnO_4^- + 2H_2O + 3e^- \rightleftharpoons MnO_{2(s)} + 4OH^-$	+0.60	
		$I_{2(s)} + 2e^- \rightleftharpoons 2I^-$	+0.54	
		$Cu^+ + e^- \rightleftharpoons Cu_{(s)}$	+0.52	
		$H_2SO_3 + 4H^+ + 4e^- \rightleftharpoons S_{(s)} + 3H_2O$	+0.45	
		$Cu^{2+} + 2e^- \rightleftharpoons Cu_{(s)}$	+0.34	
		$SO_4^{2-} + 4H^+ + 2e^- \rightleftharpoons H_2SO_3 + H_2O$	+0.17	
		$Cu^{2+} + e^- \rightleftharpoons Cu^+$	+0.15	
		$Sn^{4+} + 2e^- \rightleftharpoons Sn^{2+}$	+0.15	
		$S_{(s)} + 2H^+ + 2e^- \rightleftharpoons H_2S_{(g)}$	+0.14	
		$2H^+ + 2e^- \rightleftharpoons H_{2(g)}$	+0.00	
		$Pb^{2+} + 2e^- \rightleftharpoons Pb_{(s)}$	-0.13	
		$Sn^{2+} + 2e^- \rightleftharpoons Sn_{(s)}$	-0.14	
		$Ni^{2+} + 2e^- \rightleftharpoons Ni_{(s)}$	-0.26	
	$H_3PO_4 + 2H^+ + 2e^- \rightleftharpoons H_3PO_3 + H_2O$	-0.28		
	$Co^{2+} + 2e^- \rightleftharpoons Co_{(s)}$	-0.28		
	$Se_{(s)} + 2H^+ + 2e^- \rightleftharpoons H_2Se$	-0.40		
	$Cr^{3+} + e^- \rightleftharpoons Cr^{2+}$	-0.41		
	$2H_2O + 2e^- \rightleftharpoons H_2 + 2OH^-(10^{-7}M)$	-0.41		
	$Fe^{2+} + 2e^- \rightleftharpoons Fe_{(s)}$	-0.45		
	$Ag_2S_{(s)} + 2e^- \rightleftharpoons 2Ag_{(s)} + S^{2-}$	-0.69		
	$Cr^{3+} + 3e^- \rightleftharpoons Cr_{(s)}$	-0.74		
	$Zn^{2+} + 2e^- \rightleftharpoons Zn_{(s)}$	-0.76		
	$Te_{(s)} + 2H^+ + 2e^- \rightleftharpoons H_2Te$	-0.79		
	$2H_2O + 2e^- \rightleftharpoons H_{2(g)} + 2OH^-$	-0.83		
	$Mn^{2+} + 2e^- \rightleftharpoons Mn_{(s)}$	-1.19		
	$Al^{3+} + 3e^- \rightleftharpoons Al_{(s)}$	-1.66		
	$Mg^{2+} + 2e^- \rightleftharpoons Mg_{(s)}$	-2.37		
	$Na^+ + e^- \rightleftharpoons Na_{(s)}$	-2.71		
	$Ca^{2+} + 2e^- \rightleftharpoons Ca_{(s)}$	-2.87		
	$Sr^{2+} + 2e^- \rightleftharpoons Sr_{(s)}$	-2.89		
	$Ba^{2+} + 2e^- \rightleftharpoons Ba_{(s)}$	-2.91		
	$K^+ + e^- \rightleftharpoons K_{(s)}$	-2.93		
	$Rb^+ + e^- \rightleftharpoons Rb_{(s)}$	-2.98		
	$Cs^+ + e^- \rightleftharpoons Cs_{(s)}$	-3.03		
	$Li^+ + e^- \rightleftharpoons Li_{(s)}$	-3.04		

Overpotential Effect

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