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Chemistry 12

APRIL 2002

Course Code = CH

Student Instructions

1. Place 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.

Question 1:

1. .

(3)

Question 8:

8. .

(2)

Question 2:

2. .

(2)

Question 9:

9. .

(5)

Question 3:

3. .

(2)

Question 10:

10. .

(3)

Question 4:

4. .

(4)

Question 11:

11. .

(4)

Question 5:

5. .

(5)

Question 12:

12. .

(2)

Question 6:

6. .

(3)

Question 13:

13. .

(3)

Question 7:

7. .

(2)

CHEMISTRY 12

APRIL 2002

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	60	70
PART B: 13 written-response questions	40	50
Total:	100 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: 60 marks

Suggested Time: 70 minutes

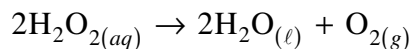
INSTRUCTIONS: For each question, select the **best** answer and record your choice on the Response Form provided. Using an HB pencil, completely fill in the circle that has the letter corresponding to your answer.

Selected multiple-choice questions are worth 2 marks.

1. Which of the following could be used to describe the rate of a reaction? **(1 mark)**

- A. $\frac{\text{change in time}}{\text{change in mass}}$
- B. $\frac{\text{change in mass}}{\text{change in volume}}$
- C. $\frac{\text{change in volume}}{\text{change in time}}$
- D. $\frac{\text{change in volume}}{\text{change in mass}}$

2. Consider the following reaction:



Which factor explains why the above reaction speeds up in the presence of $\text{MnO}_{2(s)}$?

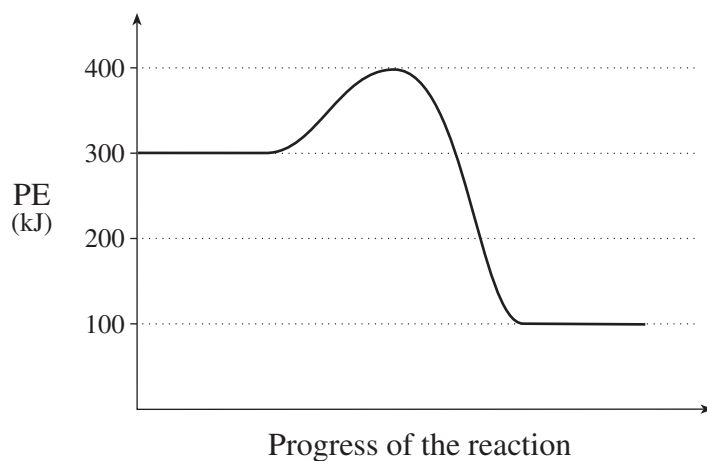
(1 mark)

- A. temperature
- B. concentration
- C. nature of reactants
- D. presence of catalyst

3. What happens to the potential energy and the total energy as an activated complex changes into products? (1 mark)

	PE	Total Energy
A.	increases	increases
B.	decreases	decreases
C.	increases	remains constant
D.	decreases	remains constant

4. Consider the following PE diagram: (1 mark)

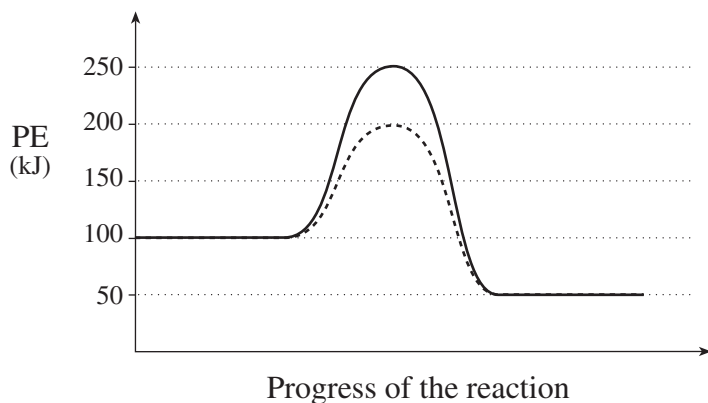


Which of the following describes the type of reaction and ΔH for the **reverse** reaction?

	Type of Reaction	ΔH (kJ)
A.	exothermic	positive
B.	endothermic	positive
C.	exothermic	negative
D.	endothermic	negative

5. Consider the following diagram for a catalyzed and uncatalyzed reaction:

(2 marks)



Which of the following describes the **forward** reaction?

	Reaction	Activation Energy (kJ)	ΔH (kJ)
A.	catalyzed	100	-50
B.	uncatalyzed	100	-50
C.	catalyzed	150	+50
D.	uncatalyzed	150	+50

6. Consider the following reaction mechanism:

(1 mark)

Step 1	$\text{NO}_2 + \text{SO}_2 \rightarrow \text{SO}_3 + \text{NO}$
Step 2	$\text{NO} + \frac{1}{2}\text{O}_2 \rightarrow \text{NO}_2$

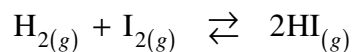
Identify the catalyst.

- A. O_2
- B. NO
- C. SO_2
- D. NO_2

OVER

7. Consider the following:

(1 mark)

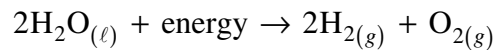


Initially, HI is added to an empty flask. How do the rates of the forward and reverse reactions change as the system proceeds to equilibrium?

	Forward Rate	Reverse Rate
A.	increases	increases
B.	increases	decreases
C.	decreases	decreases
D.	decreases	increases

8. Consider the following reaction:

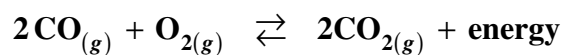
(2 marks)



Determine the enthalpy and entropy changes for the above reaction?

	Enthalpy	Entropy
A.	increases	decreases
B.	decreases	increases
C.	increases	increases
D.	decreases	decreases

Use the following equilibrium equation to answer questions 9 and 10.



9. Which of the following two stresses will each cause the system to shift to the right?

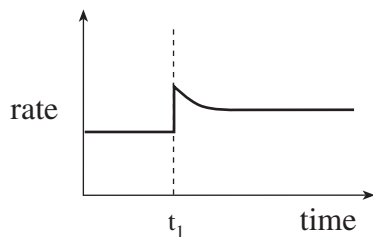
(1 mark)

- A. increase temperature, increase volume
- B. decrease temperature, increase volume
- C. increase temperature, decrease volume
- D. decrease temperature, decrease volume

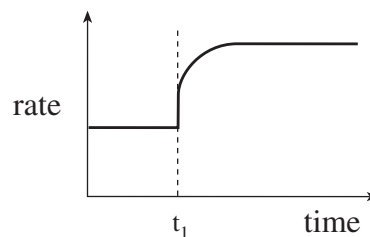
10. Which of the following shows the forward rate of reaction when the temperature of the system is increased at time = t_1 ?

(1 mark)

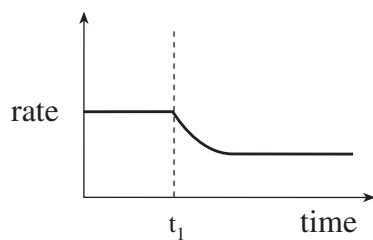
A.



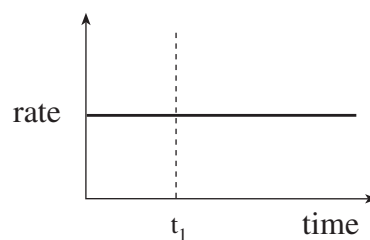
B.



C.

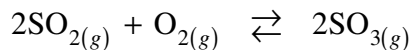


D.



11. Consider the following:

(1 mark)

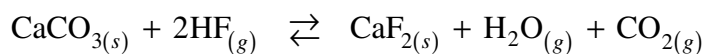


Initially, 0.030 mol SO_2 and 0.030 mol O_2 are placed into a 1.0 L container. At equilibrium, there is 0.020 mol O_2 present. What is the $[\text{SO}_2]$ at equilibrium?

- A. 0.010 mol/L
- B. 0.020 mol/L
- C. 0.030 mol/L
- D. 0.040 mol/L

12. What is the equilibrium expression for the following system?

(1 mark)



- A. $K_{eq} = \frac{[\text{HF}]^2}{[\text{H}_2\text{O}][\text{CO}_2]}$
- B. $K_{eq} = \frac{[\text{H}_2\text{O}][\text{CO}_2]}{[\text{HF}]^2}$
- C. $K_{eq} = \frac{[\text{H}_2\text{O}][\text{CO}_2]}{[\text{CaCO}_3][\text{HF}]^2}$
- D. $K_{eq} = \frac{[\text{CaF}_2][\text{H}_2\text{O}][\text{CO}_2]}{[\text{CaCO}_3][\text{HF}]^2}$

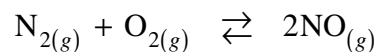
13. What will cause the K_{eq} for an endothermic reaction to decrease?

(1 mark)

- A. adding a catalyst
- B. increasing the surface area
- C. increasing the temperature
- D. decreasing the temperature

14. Consider the following equilibrium:

(2 marks)



An equilibrium mixture consists of 1.0×10^{-1} mol N_2 , 2.0×10^{-1} mol O_2 and 3.0×10^{-3} mol NO in a 1.0L container. What is the value of K_{eq} ?

- A. 4.5×10^{-4}
- B. 2.2×10^{-4}
- C. 1.5×10^{-1}
- D. 3.0×10^{-1}

15. Which of the following will dissolve in water to form an ionic solution?

(1 mark)

- A. O_2
- B. CH_4
- C. NH_4Cl
- D. CH_3OH

16. The solubility of SrCO_3 is 2.4×10^{-5} M . How many moles of dissolved solute are present in 100.0 mL of saturated SrCO_3 solution?

(1 mark)

- A. 5.6×10^{-10} mol
- B. 2.4×10^{-6} mol
- C. 2.4×10^{-5} mol
- D. 2.4×10^{-4} mol

17. What are the ion concentrations in 0.30 M CuCl_2 ?

(1 mark)

	$[\text{Cu}^{2+}]$	$[\text{Cl}^-]$
A.	0.10 M	0.20 M
B.	0.20 M	0.10 M
C.	0.30 M	0.30 M
D.	0.30 M	0.60 M

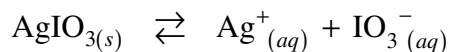
18. What is the net ionic equation for the reaction that occurs when equal volumes of 0.20 M $\text{Ba}(\text{NO}_3)_2$ and 0.20 M Na_2SO_4 are mixed together?

(1 mark)

- A. $\text{Ba}^{2+}_{(aq)} + \text{SO}_4^{2-}_{(aq)} \rightarrow \text{BaSO}_{4(s)}$
- B. $\text{Na}^+_{(aq)} + \text{NO}_3^-_{(aq)} \rightarrow \text{NaNO}_{3(s)}$
- C. $\text{Ba}(\text{NO}_3)_{2(aq)} + \text{Na}_2\text{SO}_{4(aq)} \rightarrow \text{BaSO}_{4(s)} + 2\text{NaNO}_{3(aq)}$
- D. $\text{Ba}^{2+}_{(aq)} + 2\text{NO}_3^-_{(aq)} + 2\text{Na}^+_{(aq)} + \text{SO}_4^{2-}_{(aq)} \rightarrow \text{BaSO}_{4(s)} + 2\text{Na}^+_{(aq)} + 2\text{NO}_3^-_{(aq)}$

19. Consider the following equilibrium:

(2 marks)



A few crystals of NaIO_3 are added to the above equilibrium. When equilibrium is re-established, how do the new ion concentrations compare with the original equilibrium concentrations?

	$[\text{Ag}^+]$	$[\text{IO}_3^-]$
A.	decreased	decreased
B.	decreased	increased
C.	increased	decreased
D.	increased	increased

20. The K_{sp} expression for $Zn(OH)_2$ is

(1 mark)

- A. $K_{sp} = [Zn^{2+}][OH^-]^2$
- B. $K_{sp} = [Zn^{2+}]^2[OH^-]$
- C. $K_{sp} = [Zn^{2+}][2OH^-]$
- D. $K_{sp} = [Zn^{2+}][2OH^-]^2$

21. The solubility of $CdCO_3$ is $2.5 \times 10^{-6} M$. Calculate the K_{sp} value for $CdCO_3$.

(1 mark)

- A. 6.3×10^{-12}
- B. 2.5×10^{-6}
- C. 5.0×10^{-6}
- D. 1.6×10^{-3}

22. At $25^\circ C$, what is the $[Cl^-]$ in a saturated solution of $PbCl_2$?

(2 marks)

- A. $1.4 \times 10^{-2} M$
- B. $2.3 \times 10^{-2} M$
- C. $2.9 \times 10^{-2} M$
- D. $4.6 \times 10^{-2} M$

23. The property common to both 0.10 M HCl and 0.10 M NaOH is that both solutions

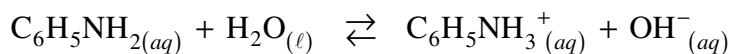
(1 mark)

- A. taste bitter.
- B. have a $pH > 7$.
- C. conduct electricity.
- D. react with magnesium to produce hydrogen gas.

OVER

24. Consider the following Brønsted-Lowry equilibrium:

(1 mark)

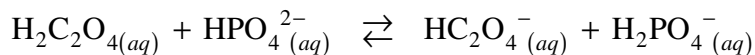


The substances acting as acids and bases from left to right are

- A. acid, base, acid, base.
- B. acid, base, base, acid.
- C. base, acid, acid, base.
- D. base, acid, base, acid.

25. Consider the following equilibrium:

(1 mark)



In the above equilibrium, a conjugate pair is

- A. HPO_4^{2-} and HC_2O_4^-
- B. HPO_4^{2-} and H_2PO_4^-
- C. $\text{H}_2\text{C}_2\text{O}_4$ and HPO_4^{2-}
- D. $\text{H}_2\text{C}_2\text{O}_4$ and H_2PO_4^-

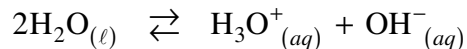
26. The strength of the acids HCl, H_2SO_3 and H_3PO_4 from the weakest to strongest is

(1 mark)

- A. HCl, H_3PO_4 , H_2SO_3
- B. HCl, H_2SO_3 , H_3PO_4
- C. H_2SO_3 , H_3PO_4 , HCl
- D. H_3PO_4 , H_2SO_3 , HCl

27. Consider the following equilibrium at 25°C :

(2 marks)



What happens to $[\text{OH}^-]$ and pH as 0.1 M HCl is added?

- A. $[\text{OH}^-]$ decreases and pH increases.
- B. $[\text{OH}^-]$ decreases and pH decreases.
- C. $[\text{OH}^-]$ increases and pH increases.
- D. $[\text{OH}^-]$ increases and pH decreases.

28. What is the value of the ionization constant for water at 25°C ?

(1 mark)

- A. 7.0
- B. 14.0
- C. 1.0×10^{-7}
- D. 1.0×10^{-14}

29. Which of the following equations represents the dissociation of $\text{Sr}(\text{NO}_3)_2$ in water?

(1 mark)

- A. $\text{Sr}(\text{NO}_3)_{2(s)} \rightarrow \text{Sr}^{2+}_{(aq)} + 6\text{NO}^-_{(aq)}$
- B. $\text{Sr}(\text{NO}_3)_{2(s)} \rightarrow \text{Sr}^{2+}_{(aq)} + 2\text{NO}_3^-_{(aq)}$
- C. $\text{Sr}(\text{NO}_3)_{2(s)} \rightarrow 2\text{Sr}^{2+}_{(aq)} + \text{NO}_3^-_{(aq)}$
- D. $\text{Sr}(\text{NO}_3)_{2(s)} \rightarrow \text{Sr}^{2+}_{(aq)} + (\text{NO}_3)_2^{2-}_{(aq)}$

30. What is the equilibrium constant expression representing the predominant reaction for the hydrolysis of $\text{NaHCO}_3(aq)$? **(2 marks)**
- A. $K_w = [\text{H}_3\text{O}^+][\text{OH}^-]$
- B. $K_{eq} = \frac{[\text{Na}^+][\text{HCO}_3^-]}{[\text{NaHCO}_3]}$
- C. $K_a = \frac{[\text{H}_3\text{O}^+][\text{CO}_3^{2-}]}{[\text{HCO}_3^-]}$
- D. $K_b = \frac{[\text{H}_2\text{CO}_3][\text{OH}^-]}{[\text{HCO}_3^-]}$
31. Which of the following salt solutions will be neutral? **(1 mark)**
- A. 1.0 M NH_4Cl
- B. 1.0 M LiClO_4
- C. 1.0 M $\text{K}_2\text{C}_2\text{O}_4$
- D. 1.0 M NaHCO_3
32. The chemical indicator bromthymol blue changes from yellow to blue as a result of the addition of **(1 mark)**
- A. 1.0 M HCl
- B. 1.0 M HNO_2
- C. 1.0 M K_2CO_3
- D. 1.0 M NH_4Cl
33. A chemical indicator has a $K_a = 1.0 \times 10^{-6}$. Determine the identity of this indicator. **(1 mark)**
- A. phenol red
- B. thymol blue
- C. phenolphthalein
- D. chlorophenol red

34. Pure sodium hydrogen phthalate is used to standardize a solution of NaOH for use in an acid-base titration. What term is used to describe the sodium hydrogen phthalate? (1 mark)

- A. titrant base
- B. standard buffer
- C. equivalent base
- D. primary standard

35. Calculate the volume of 0.500 M NaOH required to completely neutralize 25.0 mL of 0.450 M H₂SO₄ . (2 marks)

- A. 9.00 mL
- B. 11.3 mL
- C. 22.5 mL
- D. 45.0 mL

36. Which of the following is the net ionic equation for the neutralization of CH₃COOH with NaOH ? (1 mark)

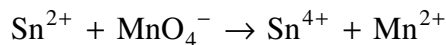
- A. $\text{CH}_3\text{COO}^-_{(aq)} + \text{OH}^-_{(aq)} \rightarrow \text{CH}_3\text{COOH}_{(aq)} + \text{O}^{2-}_{(aq)}$
- B. $\text{CH}_3\text{COOH}_{(aq)} + \text{OH}^-_{(aq)} \rightarrow \text{H}_2\text{O}_{(\ell)} + \text{CH}_3\text{COO}^-_{(aq)}$
- C. $\text{CH}_3\text{COOH}_{(aq)} + \text{NaOH}_{(aq)} \rightarrow \text{NaCH}_3\text{COO}_{(aq)} + \text{H}_2\text{O}_{(\ell)}$
- D. $\text{CH}_3\text{COO}^-_{(aq)} + \text{H}^+_{(aq)} + \text{Na}^+_{(aq)} + \text{OH}^-_{(aq)} \rightarrow \text{Na}^+_{(aq)} + \text{CH}_3\text{COO}^-_{(aq)} + \text{H}_2\text{O}_{(\ell)}$

37. The pH of normal rainwater is (2 marks)

- A. less than 7.0 due to dissolved SO_{2(g)}
- B. less than 7.0 due to dissolved CO_{2(g)}
- C. greater than 7.0 due to dissolved CO_{2(g)}
- D. equal to 7.0 due to dissolved N₂ and O₂

38. Which of the following describes a strong oxidizing agent? **(1 mark)**
- A. a substance which loses electrons readily
 - B. a substance which gains electrons readily
 - C. a substance which has a large increase in oxidation number
 - D. a substance which has a small increase in oxidation number

39. Consider the following unbalanced redox reaction: **(2 marks)**



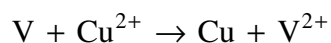
Which of the following describes the change in Sn^{2+} ?

- A. loses electrons and is reduced
 - B. gains electrons and is reduced
 - C. loses electrons and is oxidized
 - D. gains electrons and is oxidized
40. A solution containing Pd^{2+} reacts spontaneously with Ga to produce Pd and Ga^{3+} . However, a solution containing Pd^{2+} does not react with Pt . The metals, in order of increasing strength as reducing agents, are **(1 mark)**
- A. Pt < Pd < Ga
 - B. Pt < Ga < Pd
 - C. Ga < Pt < Pd
 - D. Ga < Pd < Pt

41. Which of the following can act as an oxidizing agent, but **not** as a reducing agent? **(1 mark)**

- A. Cr
- B. Cl^-
- C. Cu^+
- D. Na^+

42. Solid copper forms spontaneously in the following reaction: **(1 mark)**



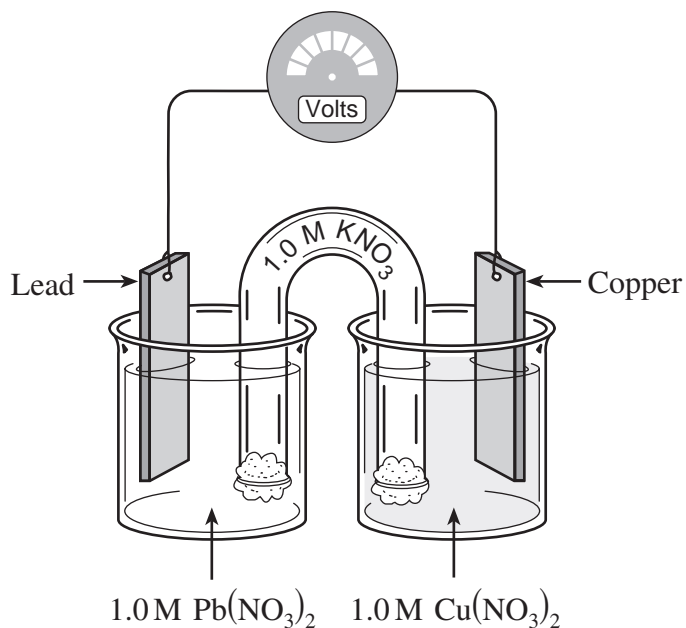
Based on this observation, Cu^{2+} is a

- A. weaker reducing agent than V^{2+}
- B. weaker oxidizing agent than V^{2+}
- C. stronger reducing agent than V^{2+}
- D. stronger oxidizing agent than V^{2+}

43. Which of the following could be used to determine the $[\text{Fe}^{2+}]$ by a redox titration? **(1 mark)**

- A. I_2
- B. Cl^-
- C. Cu^{2+}
- D. MnO_4^- (acidified)

Use the following diagram to answer questions 44, 45 and 46.



44. What happens to the lead electrode? **(2 marks)**
- A. It loses mass as it is reduced.
 - B. It gains mass as it is reduced.
 - C. It loses mass as it is oxidized.
 - D. It gains mass as it is oxidized.
45. As the cell operates, what happens to the ions in the salt bridge? **(1 mark)**
- A. K^+ and NO_3^- will both migrate toward the Pb half-cell.
 - B. K^+ and NO_3^- will both migrate toward the Cu half-cell.
 - C. K^+ will migrate toward the Cu half-cell and NO_3^- will migrate toward the Pb half-cell.
 - D. K^+ will migrate toward the Pb half-cell and NO_3^- will migrate toward the Cu half-cell.
46. What is the initial cell voltage? **(1 mark)**
- A. +0.02 V
 - B. +0.21 V
 - C. +0.28 V
 - D. +0.47 V

47. Consider the following:

(2 marks)

I.	electrolysis of water
II.	electroplating of copper
III.	rusting of iron

Which of the above involve non-spontaneous redox reactions?

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

48. A copper spoon was electroplated with silver. Which of the following reactions occurred at the cathode during electroplating?

(1 mark)

- A. $\text{Ag} \rightarrow \text{Ag}^+ + \text{e}^-$
- B. $\text{Ag}^+ + \text{e}^- \rightarrow \text{Ag}$
- C. $\text{Cu} \rightarrow \text{Cu}^{2+} + 2\text{e}^-$
- D. $\text{Cu}^{2+} + 2\text{e}^- \rightarrow \text{Cu}$

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

OVER

PART B: WRITTEN RESPONSE

Value: 40 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.

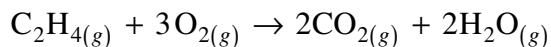
Your steps and assumptions leading to a solution must be written in the spaces below the questions.

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

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

1. Consider the reaction:

(3 marks)



At certain conditions, 0.15 mol CO_2 is produced in 2.0 minutes.
What is the rate of consumption of C_2H_4 in g/s ?

2. Define the term *reaction mechanism*.

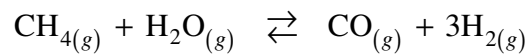
(2 marks)

3. State *Le Chatelier's Principle*.

(2 marks)

4. Consider the following:

(4 marks)



Initially, 0.060 mol CH_4 , 0.080 mol H_2O , 0.280 mol CO and 0.740 mol H_2 are placed into a 4.00 L container. At equilibrium, the $[\text{H}_2] = 0.200 \text{ mol/L}$. What is the value of K_{eq} ?

5. A 30.00 mL sample of a saturated solution of Ag_2SO_4 was heated in an evaporating dish until all the water was evaporated. The following data were recorded:

Volume of solution	30.00 mL
Mass of evaporating dish	32.125 g
Mass of evaporating dish and solid Ag_2SO_4	32.260 g

Calculate the K_{sp} value for Ag_2SO_4 .

(5 marks)

6. The ion H_2PO_4^- is an amphiprotic anion.

a) Define the term *amphiprotic*.

(1 mark)

b) Write the balanced equation for the reaction when H_2PO_4^- reacts with HF .

(2 marks)

7. Write an equation for a reaction in which H_2O acts only as a Brønsted-Lowry base.

(2 marks)

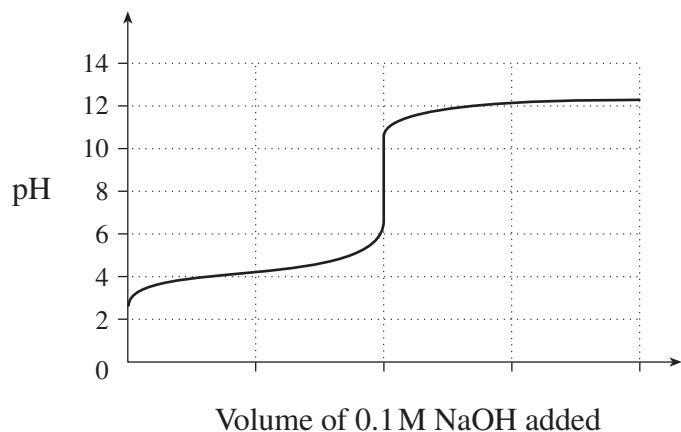
8. Calculate the pH of 0.25 M $\text{Sr}(\text{OH})_2$.

(2 marks)

9. Calculate the pH of 0.25M NH_4Cl .

(5 marks)

10. A 0.1 M unknown acid is titrated with 0.10 M NaOH and the following titration curve results:



- a) Choose a suitable indicator (other than phenolphthalein) and give a reason for your choice. **(1 mark)**

Suitable Indicator: _____

Reason: _____

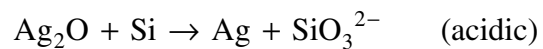
- b) Is the unknown acid weak or strong? Explain. **(2 marks)**

Unknown Acid: _____

Explanation: _____

11. Balance the following redox reaction:

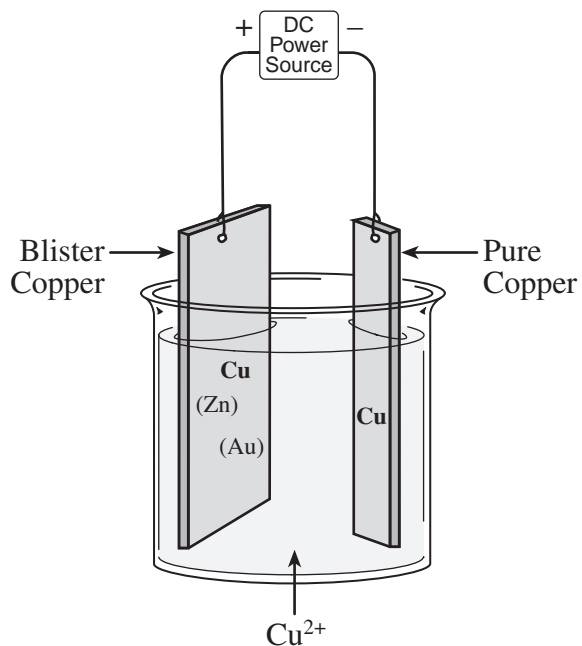
(4 marks)



12. Sodium metal is produced commercially by the electrolysis of molten $\text{NaCl}_{(l)}$.
Explain why sodium metal, $\text{Na}_{(s)}$, cannot be produced by electrolysis of
aqueous $\text{NaCl}_{(aq)}$.

(2 marks)

13. Blister copper is an impure sample of copper containing small amounts of zinc and gold. Blister copper is purified using electrolysis.



Sufficient voltage is supplied to oxidize copper at the anode.

- a) What happens to the zinc at the anode? Explain. (2 marks)

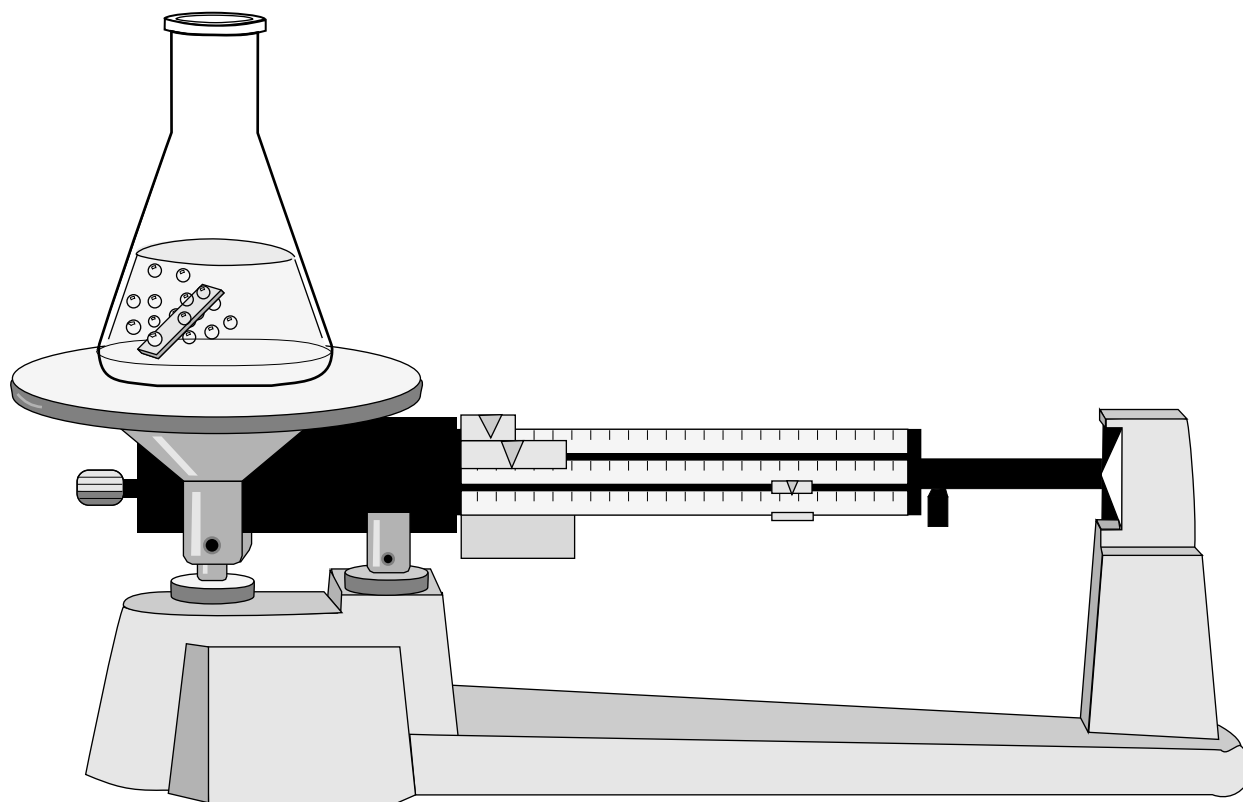
- b) Write the equation for the half-reaction that occurs at the cathode. (1 mark)

END OF EXAMINATION

Data Booklet

CHEMISTRY 12

Work done in this booklet
will not be marked.



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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)
STRENGTH OF OXIDIZING AGENT		$F_{2(g)} + 2e^- \rightleftharpoons 2F^-$	+2.87
		$S_2O_8^{2-} + 2e^- \rightleftharpoons 2SO_4^{2-}$	+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	

WEAK
STRENGTH OF REDUCING AGENT
STRONG

Overpotential Effect

Overpotential Effect