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BRITISH COLUMBIA

Chemistry 12

AUGUST 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. . (3)

Question 2:

2. . (2)

Question 9:

9. . (4)

Question 3:

3. . (2)

Question 10:

10. . (3)

Question 4:

4. . (4)

Question 11:

11. . (4)

Question 5:

5. . (3)

Question 12:

12. . (2)

Question 6:

6. . (3)

Question 13:

13. . (3)

Question 7:

7. . (4)

CHEMISTRY 12

AUGUST 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

1. This examination consists of **two** parts:

	Value	Suggested Time
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. $\frac{\text{change in time}}{\text{change in concentration}}$

   B. $\frac{\text{change in mass}}{\text{change in concentration}}$

   C. $\frac{\text{change in concentration}}{\text{change in time}}$

   D. $\frac{\text{change in concentration}}{\text{change in mass}}$

2. Which factor explains why coal dust is explosive? **(1 mark)**

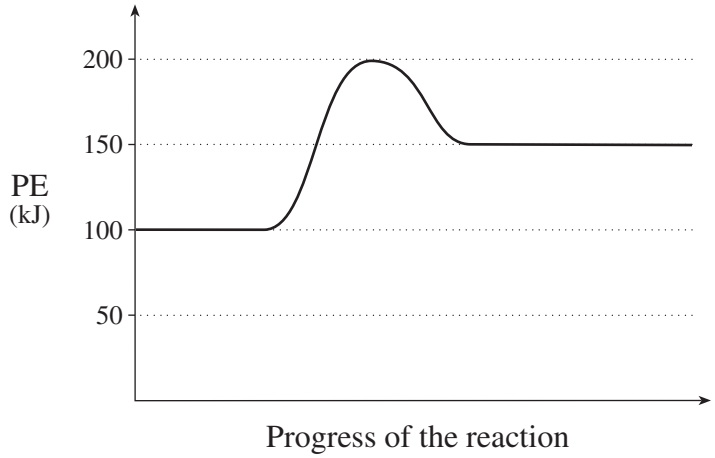
   A. temperature
   B. surface area
   C. concentration
   D. addition of catalyst

3. As an activated complex changes into products, what changes occur in the chemical bonds of the activated complex and the PE of the system? **(1 mark)**

	Bonds	PE
A.	form	increases
B.	form	decreases
C.	break	increases
D.	break	decreases

OVER

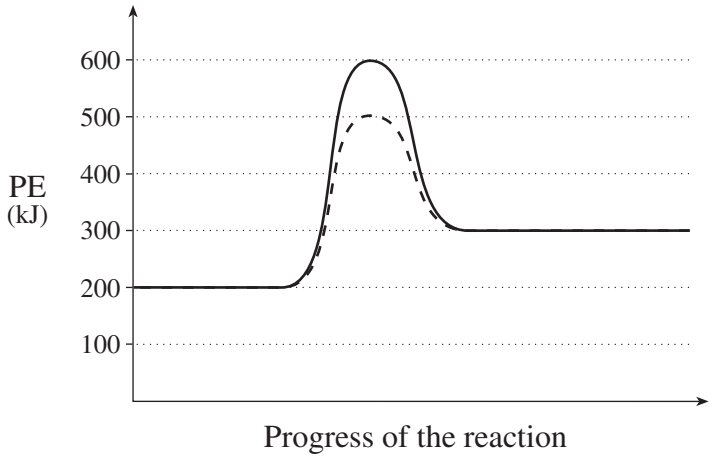
4. Consider the following PE diagram: **(1 mark)**



Which of the following describes ΔH and the type of reaction in the forward direction?

	ΔH (kJ)	Type of Reaction
A.	−50	exothermic
B.	−50	endothermic
C.	+50	exothermic
D.	+50	endothermic

5. Consider the following PE 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	300	−100
B.	uncatalyzed	300	−100
C.	catalyzed	400	+100
D.	uncatalyzed	400	+100

6. Consider the following reaction mechanism: **(1 mark)**

Step 1	$NOCl \rightarrow NO + Cl$
Step 2	$NOCl + Cl \rightarrow NO + Cl_2$

Identify the reaction intermediate.

A. Cl
B. Cl_2
C. NO
D. NOCl

OVER

7. Consider the following: **(1 mark)**

$$2NH_{3(g)} \rightleftarrows N_{2(g)} + 3H_{2(g)}$$

Initially, NH_3 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	increases
D.	decreases	decreases

8. Consider the following: **(2 marks)**

$$H_{2(g)} + Br_{2(\ell)} \overset{?}{\rightleftarrows} 2HBr_{(g)} + \text{energy}$$

What positions do minimum enthalpy and maximum entropy tend toward?

	Minimum Enthalpy	Maximum Entropy
A.	products	products
B.	products	reactants
C.	reactants	products
D.	reactants	reactants

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

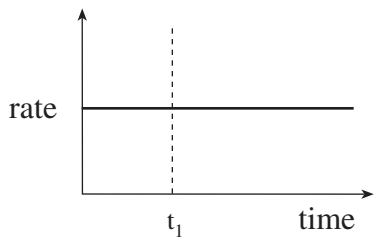
$$H_{2(g)} + I_{2(g)} \rightleftarrows 2HI_{(g)} + \text{energy}$$

9. Which of the following stresses will **not** cause a shift in equilibrium? **(1 mark)**

   A. decrease $[I_2]$
   B. increase $[H_2]$
   C. decrease volume
   D. increase temperature

10. Which of the following shows the **reverse** rate of reaction when the volume is decreased at time = t_1 ? **(1 mark)**

A.



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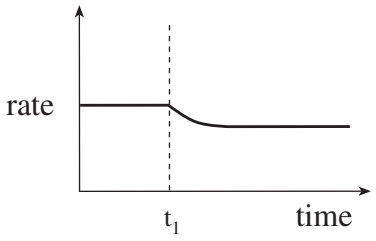
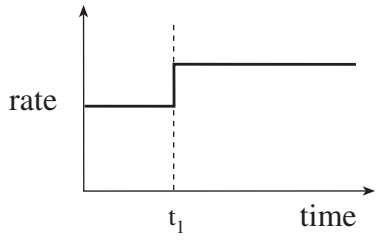
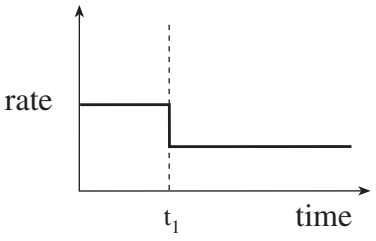


C.



D.



OVER

11. Consider the following: **(1 mark)**

$$2SO_{3(g)} \rightleftarrows 2SO_{2(g)} + O_{2(g)}$$

Initially, some SO_3 is placed into a $3.0\,L$ container. At equilibrium there is $0.030\,mol$ SO_2 present. What is the $[O_2]$ at equilibrium?

A. 0.0050 mol/L
B. 0.010 mol/L
C. 0.015 mol/L
D. 0.030 mol/L

12. Which reaction has the following equilibrium expression? **(1 mark)**

$$K_{eq} = \frac{[PCl_5]}{[PCl_3][Cl_2]}$$

A. $PCl_{3(g)} + Cl_{2(g)} \rightleftarrows PCl_{5(g)}$
B. $PCl_{3(g)} + Cl_{2(\ell)} \rightleftarrows PCl_{5(g)}$
C. $PCl_{5(g)} \rightleftarrows PCl_{3(g)} + Cl_{2(g)}$
D. $PCl_{5(g)} \rightleftarrows PCl_{3(g)} + Cl_{2(\ell)}$

13. What will cause the value of K_{eq} for an exothermic reaction to decrease? **(1 mark)**

A. increasing the pressure
B. increasing the temperature
C. decreasing the temperature
D. decreasing the surface area

14. Consider the following equilibrium: **(2 marks)**

$$H_{2(g)} + I_{2(g)} \rightleftarrows 2HI_{(g)}$$

An equilibrium mixture contains 1.0×10^{-3} mol H_2 , 2.0×10^{-3} mol I_2 and 1.0×10^{-2} mol HI in a 1.0 L container. What is the value of K_{eq} ?

A. 2.0×10^{-2}
B. 5.0×10^{1}
C. 5.0×10^{3}
D. 1.0×10^{4}

15. Which of the following could be used to express solubility? **(1 mark)**

A. mol
B. M/s
C. g/mL
D. mL/min

16. When 100.0 mL of a saturated solution of BaF_2 is heated and all the water is evaporated, 3.6×10^{-4} mol of solute remains. The solubility of BaF_2 is **(1 mark)**

A. 1.9×10^{-10} M
B. 1.3×10^{-5} M
C. 3.6×10^{-4} M
D. 3.6×10^{-3} M

OVER

17. A solution contains both $0.2\,\text{M}\ \text{Mg}^{2+}_{(aq)}$ and $0.2\,\text{M}\ \text{Sr}^{2+}_{(aq)}$. These ions can be removed separately through precipitation by adding equal volumes of $0.2\,\text{M}$ solutions of **(1 mark)**

A. OH^-, and then S^{2-}

B. Cl^-, and then OH^-

C. CO_3^{2-}, and then SO_3^{2-}

D. SO_4^{2-}, and then PO_4^{3-}

18. Consider the following equilibrium: **(1 mark)**

$$\text{CaSO}_{4(s)} \rightleftarrows \text{Ca}^{2+}_{(aq)} + \text{SO}_4^{2-}{}_{(aq)}$$

Which of the following would shift the above equilibrium to the left?

A. adding $\text{CaSO}_{4(s)}$

B. adding $\text{MgSO}_{4(s)}$

C. removing some $\text{Ca}^{2+}_{(aq)}$

D. removing some $\text{SO}_4^{2-}{}_{(aq)}$

19. Calculate the solubility of CaC_2O_4. **(1 mark)**

A. $2.3 \times 10^{-9}\,\text{M}$

B. $1.2 \times 10^{-5}\,\text{M}$

C. $4.8 \times 10^{-5}\,\text{M}$

D. $8.3 \times 10^{-4}\,\text{M}$

20. How many moles of dissolved solute are present in 100.0 mL of a saturated $SrCO_3$ solution? **(2 marks)**

A. 5.6×10^{-11} mol
B. 2.4×10^{-6} mol
C. 2.4×10^{-5} mol
D. 2.4×10^{-4} mol

21. What happens when equal volumes of 0.2 M $AgNO_3$ and 0.2 M NaCl are combined? **(2 marks)**

A. A precipitate forms because the trial ion product > K_{sp}
B. A precipitate forms because the trial ion product < K_{sp}
C. No precipitate forms because the trial ion product > K_{sp}
D. No precipitate forms because the trial ion product < K_{sp}

22. Determine the maximum $[Na_2CO_3]$ that can exist in 1.0 L of 0.0010 M $Ba(NO_3)_2$ without forming a precipitate. **(1 mark)**

A. 2.6×10^{-12} M
B. 2.6×10^{-9} M
C. 2.6×10^{-6} M
D. 5.1×10^{-5} M

23. A *Brønsted-Lowry acid* is defined as a substance that **(1 mark)**

A. releases $H^+_{(aq)}$
B. releases $OH^-_{(aq)}$
C. accepts a proton
D. donates a proton

OVER

24. Which of the following represents the reaction of $H_2PO_4^-$ acting as an acid? **(1 mark)**

A. $H_2PO_4^- + H_2O \rightleftarrows H_3PO_4 + OH^-$

B. $H_2PO_4^- + H_2O \rightleftarrows H_3O^+ + H_3PO_4$

C. $H_2PO_4^- + H_2O \rightleftarrows H_3O^+ + HPO_4^{2-}$

D. $H_2PO_4^- + 2H_2O \rightleftarrows H_4PO_4^+ + 2OH^-$

25. Consider the following equilibrium: **(1 mark)**

$$HS^- + H_3BO_3 \rightleftarrows H_2BO_3^- + H_2S$$

The two species acting as Brønsted-Lowry bases in the above equilibrium are

A. HS^- and H_2S

B. H_3BO_3 and H_2S

C. HS^- and $H_2BO_3^-$

D. H_3BO_3 and $H_2BO_3^-$

26. List the bases $C_2O_4^{2-}$, NH_3 , and PO_4^{3-} in order from strongest to weakest. **(1 mark)**

A. $PO_4^{3-} > NH_3 > C_2O_4^{2-}$

B. $C_2O_4^{2-} > NH_3 > PO_4^{3-}$

C. $NH_3 > PO_4^{3-} > C_2O_4^{2-}$

D. $PO_4^{3-} > C_2O_4^{2-} > NH_3$

27. A basic solution can be defined as one in which **(1 mark)**

A. $\left[H_3O^+\right]$ is not present

B. $\left[H_3O^+\right]$ is equal to $\left[OH^-\right]$

C. $\left[H_3O^+\right]$ is less than $\left[OH^-\right]$

D. $\left[H_3O^+\right]$ is greater than $\left[OH^-\right]$

28. What is the $\left[H_3O^+\right]$ in $0.025\,M$ HNO_3 ? **(1 mark)**

A. $4.0 \times 10^{-13}\,M$

B. $0.025\,M$

C. $1.60\,M$

D. $12.40\,M$

29. Write the base ionization constant expression for **(1 mark)**

$$NH_{3(aq)} + H_2O_{(\ell)} \rightleftarrows NH_4^+{}_{(aq)} + OH^-_{(aq)}$$

A. $K_b = \dfrac{\left[NH_3\right]}{\left[NH_4^+\right]\left[OH^-\right]}$

B. $K_b = \dfrac{\left[NH_4^+\right]\left[OH^-\right]}{\left[NH_3\right]}$

C. $K_b = \dfrac{\left[NH_3\right]\left[H_2O\right]}{\left[NH_4^+\right]\left[OH^-\right]}$

D. $K_b = \dfrac{\left[NH_4^+\right]\left[OH^-\right]}{\left[NH_3\right]\left[H_2O\right]}$

OVER

30. The equation for the predominant hydrolysis of NH_4NO_3 can be represented by **(1 mark)**

A. $NH_4NO_{3(s)} \rightleftarrows NH_4^+{}_{(aq)} + NO_3^-{}_{(aq)}$

B. $NH_4^+{}_{(aq)} + H_2O_{(\ell)} \rightleftarrows H_3O^+{}_{(aq)} + NH_{3(aq)}$

C. $NO_3^-{}_{(aq)} + H_2O_{(\ell)} \rightleftarrows HNO_{3(aq)} + OH^-{}_{(aq)}$

D. $NH_4NO_{3(aq)} + H_2O_{(\ell)} \rightleftarrows H_3O^+{}_{(aq)} + NH_3NO_3^-{}_{(aq)}$

31. A solution made from baking soda $\left(NaHCO_3\right)$ has an amphiprotic anion which is **(2 marks)**

A. basic since $K_a < K_b$

B. basic since $K_a > K_b$

C. acidic since $K_a < K_b$

D. acidic since $K_a > K_b$

32. A chemical indicator in solution consists of **(1 mark)**

A. a weak acid and its conjugate acid.

B. a weak acid and its conjugate base.

C. a strong acid and its conjugate acid.

D. a strong acid and its conjugate base.

33. A chemical indicator has a transition point at a $pOH = 8.0$. Calculate its K_a value and identify the indicator. **(2 marks)**

A. $K_a = 1 \times 10^{-8}$, phenol red

B. $K_a = 1 \times 10^{-6}$, methyl red

C. $K_a = 1 \times 10^{-8}$, thymol blue

D. $K_a = 1 \times 10^{-6}$, chlorophenol red

34. In acid-base titrations, the solution of known concentration is called a(n) **(1 mark)**

A. basic solution.
B. acidic solution.
C. standard solution.
D. indicating solution.

35. During a titration, 25.0 mL of $H_3PO_{4(aq)}$ is completely neutralized by 42.6 mL of 0.20 M NaOH . Calculate the concentration of the acid. **(2 marks)**

A. 0.11 M
B. 0.17 M
C. 0.34 M
D. 1.0 M

36. Write the net ionic equation for the neutralization of $HF_{(aq)}$ with $Sr(OH)_{2(aq)}$. **(2 marks)**

A. $HF_{(aq)} + OH^-_{(aq)} \rightarrow H_2O_{(\ell)} + F^-_{(aq)}$
B. $HF_{(aq)} + H_2O_{(\ell)} \rightarrow H_3O^+_{(aq)} + F^-_{(aq)}$
C. $2HF_{(aq)} + Sr(OH)_{2(aq)} \rightarrow SrF_{2(aq)} + 2H_2O_{(\ell)}$
D. $2H^+_{(aq)} + 2F^-_{(aq)} + Sr^{2+}_{(aq)} + 2\,OH^-_{(aq)} \rightarrow SrF_{2(aq)} + 2H_2O_{(\ell)}$

37. Consider the buffer equilibrium: **(1 mark)**

$$\underset{\text{high concentration}}{HNO_{2(aq)}} + H_2O_{(\ell)} \rightleftarrows \underset{\text{low concentration}}{H_3O^+_{(aq)}} + \underset{\text{high concentration}}{NO_2^-{}_{(aq)}}$$

What happens when a small amount of $HCl_{(aq)}$ is added to the equilibrium system?

A. The pH increases slightly.
B. The pH decreases slightly.
C. The equilibrium shifts to the right.
D. The equilibrium does not shift due to the levelling effect.

OVER

38. An oxidizing agent is **(2 marks)**

A. reduced as it loses electrons.
B. reduced as it gains electrons.
C. oxidized as it loses electrons.
D. oxidized as it gains electrons.

39. Consider the following spontaneous reaction:

$$Ga^{3+} + 3Rb \rightarrow 3Rb^{+} + Ga$$

What happens in this reaction? **(1 mark)**

A. Rb is reduced.
B. Rb gains electrons.
C. Ga^{3+} loses electrons.
D. Ga^{3+} acts as an oxidizing agent.

40. What is the oxidation number of S in $S_2O_6^{2-}$? **(1 mark)**

A. +3
B. +5
C. +6
D. +7

41. Which of the following is the weakest oxidizing agent? **(1 mark)**

A. Cl_2
B. Al^{3+}
C. Sn^{2+}
D. acidified $Cr_2O_7^{2-}$

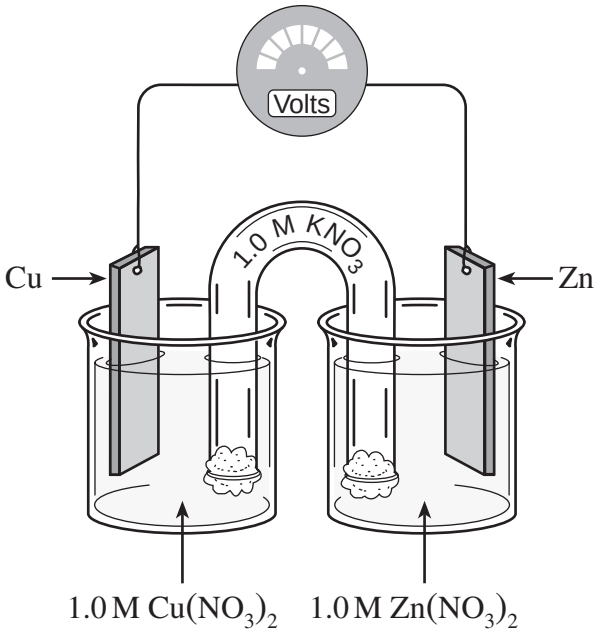
42. Which of the following could react spontaneously with Ag metal? **(1 mark)**

A. Cl^{-}
B. Fe^{2+}
C. acidified SO_4^{2-}
D. acidified NO_3^{-}

43. Which of the following could be titrated using acidified MnO_4^- ions? **(1 mark)**

A. Na^+
B. IO_3^-
C. SO_4^{2-}
D. H_2O_2

Use the following diagram to answer questions 44 and 45.



44. What happens to the zinc electrode? **(2 marks)**

A. Mass increases as it is reduced.
B. Mass decreases as it is reduced.
C. Mass increases as it is oxidized.
D. Mass decreases as it is oxidized.

45. Calculate the $E°$ for the above cell. **(1 mark)**

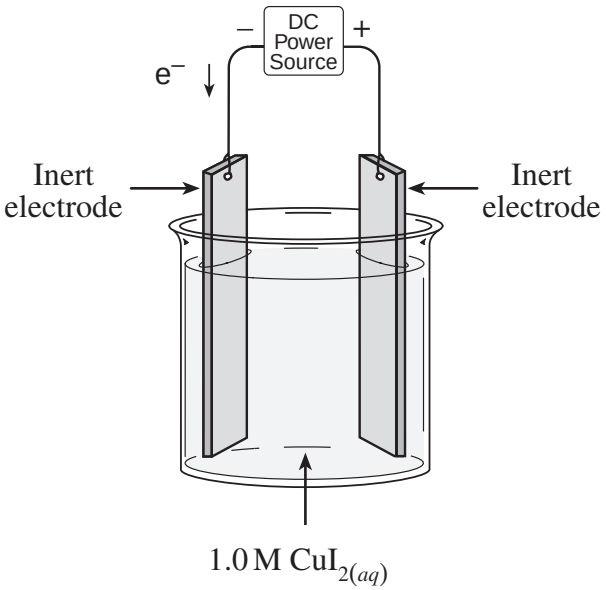
A. −0.42 V
B. 0.91 V
C. 1.10 V
D. 1.30 V

OVER

46. What happens to iron as it corrodes? **(2 marks)**

A. It loses electrons and is reduced.
B. It gains electrons and is reduced.
C. It loses electrons and is oxidized.
D. It gains electrons and is oxidized.

Use the following diagram to answer questions 47 and 48.



47. What reaction occurs at the cathode? **(1 mark)**

A. $2I^- \rightarrow I_2 + 2e^-$
B. $Cu^{2+} + 2e^- \rightarrow Cu$
C. $H_2O \rightarrow \frac{1}{2}O_2 + 2H^+ + 2e^-$
D. $2H_2O + 2e^- \rightarrow H_2 + 2OH^-$

48. What happens to the $\left[I^-\right]$ in the operating cell? **(1 mark)**

A. $\left[I^-\right]$ increases overall.
B. $\left[I^-\right]$ decreases overall.
C. $\left[I^-\right]$ remains constant overall.
D. $\left[I^-\right]$ decreases near the anode and increases near the cathode.

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

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)**

$$2H_2O_{(\ell)} \rightarrow 2H_{2(g)} + O_{2(g)}$$

The rate of production of O_2 is 1.2×10^{-2} mol/s . How many seconds will it take to decompose 100.0 g H_2O ?

2. Define the term *catalyst*. **(2 marks)**

_____

_____

3. Describe the nature of *dynamic equilibrium.* **(2 marks)**

_____

_____

OVER

4. Consider the following: **(4 marks)**

$$N_2O_{4(g)} \rightleftarrows 2NO_{2(g)} \qquad K_{eq} = 9.5 \times 10^{-3}$$

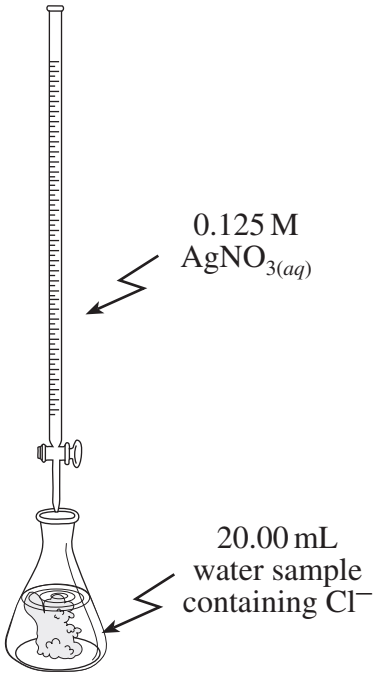
Initially, $0.060\,\text{mol}$ N_2O_4 and $0.020\,\text{mol}$ NO_2 are placed into a $2.00\,\text{L}$ container. Use calculations to determine the direction in which the reaction proceeds in order to reach equilibrium.

5. A $100.0\,\text{mL}$ saturated solution of FeF_2 contains $0.0787\,\text{g}$ of solute.
Determine $\left[Fe^{2+}\right]$ and $\left[F^{-}\right]$ in the solution. **(3 marks)**

6. Consider the following information and accompanying diagram:

In a titration experiment, $AgNO_{3(aq)}$ was used to determine the $\left[Cl^-\right]$ in a water sample and the following data were recorded:

$\left[AgNO_3\right]$	$= 0.125\,M$
Volume of water sample containing Cl^-	$= 20.00\,mL$
Initial buret reading of $AgNO_3$	$= 5.15\,mL$
Final buret reading of $AgNO_3$	$= 37.15\,mL$



The equation for this reaction is

$$Ag^+_{(aq)} + Cl^-_{(aq)} \rightarrow AgCl_{(s)}$$

Using the above data, determine the $\left[Cl^-\right]$ in the water sample. **(3 marks)**

OVER

7. Consider the following equilibria:

I.	$CH_3COOH + OCN^- \rightleftarrows HOCN + CH_3COO^-$
II.	$CH_3COOH + ClO^- \rightleftarrows HClO + CH_3COO^-$

a) In equation **I** above, the reactants are favoured. Identify the stronger acid. **(1 mark)**

b) In equation **II** above, the products are favoured. Identify the stronger acid. **(1 mark)**

c) Consider the following reaction:

$$HOCN + ClO^- \rightleftarrows OCN^- + HClO$$

Does this reaction favour reactants or products? Explain. **(2 marks)**

_____

_____

8. At 60°C, the pH = 6.51 for pure water. Determine the value of K_w at this temperature. **(3 marks)**

9. Calculate the pH of 0.35 M H_2CO_3 . **(4 marks)**

OVER

10. A strong acid–strong base titration has a pH = 7.0 at the equivalence point.
A weak acid–strong base titration has a pH > 7.0 at the equivalence point.

a) What causes the difference in these pH values? **(2 marks)**

_____

_____

_____

b) Select one indicator which could be used for both titrations. **(1 mark)**

_____

11. Balance the following redox equation: **(4 marks)**

$$ClO_3^- + S_2O_3^{2-} \rightarrow S_4O_6^{2-} + Cl^- \qquad \text{(acidic)}$$

12. State two characteristics of the overall reaction in an electrochemical cell. **(2 marks)**

i) _____

ii) _____

13. Describe two chemically different methods of preventing the corrosion of iron.
Explain how each method works. **(3 marks)**

Method 1: _____

Explanation: _____

_____

Method 2: _____

Explanation: _____

_____

END OF EXAMINATION

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Data Booklet

CHEMISTRY 12

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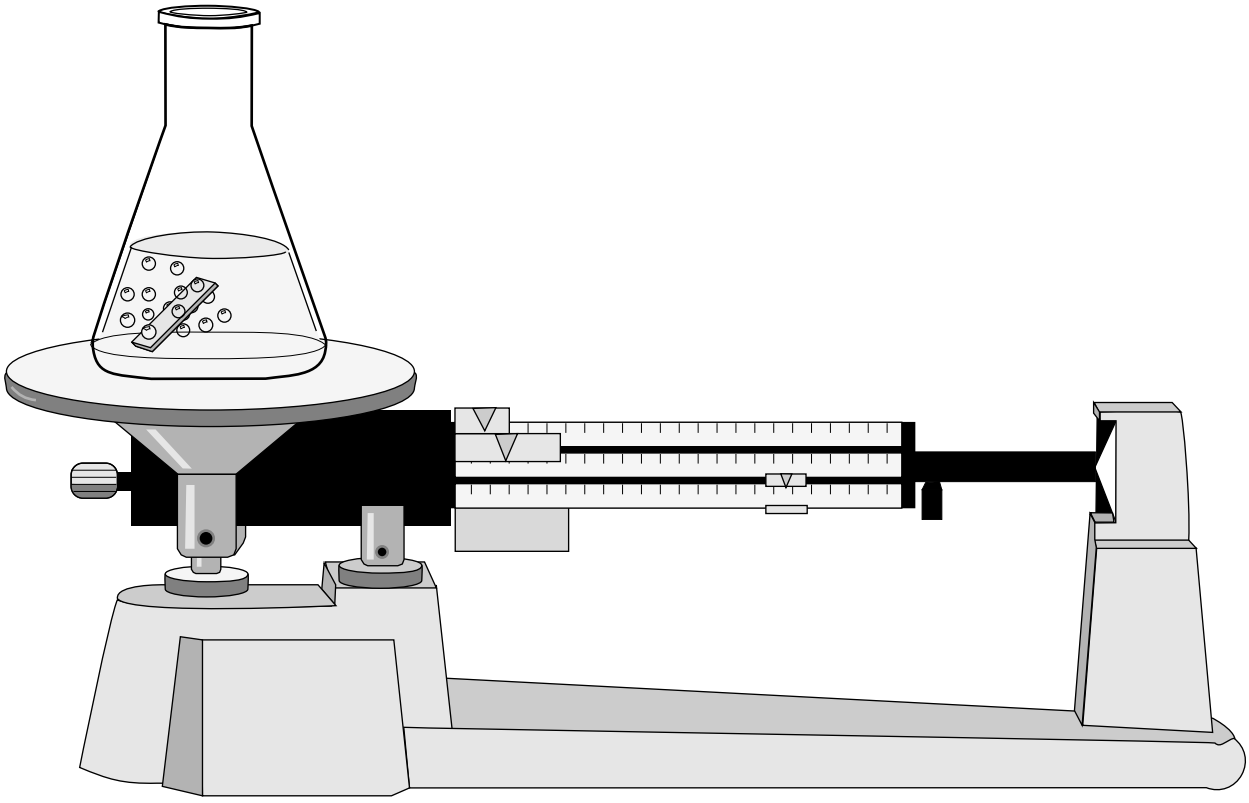

Revised January 2000

CONTENTS

REFERENCE

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

PERIODIC TABLE OF THE ELEMENTS

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1 **H** Hydrogen 1.0																	2 **He** Helium 4.0
3 **Li** Lithium 6.9	4 **Be** Beryllium 9.0											5 **B** Boron 10.8	6 **C** Carbon 12.0	7 **N** Nitrogen 14.0	8 **O** Oxygen 16.0	9 **F** Fluorine 19.0	10 **Ne** Neon 20.2
11 **Na** Sodium 23.0	12 **Mg** Magnesium 24.3											13 **Al** Aluminum 27.0	14 **Si** Silicon 28.1	15 **P** Phosphorus 31.0	16 **S** Sulphur 32.1	17 **Cl** Chlorine 35.5	18 **Ar** Argon 39.9
19 **K** Potassium 39.1	20 **Ca** Calcium 40.1	21 **Sc** Scandium 45.0	22 **Ti** Titanium 47.9	23 **V** Vanadium 50.9	24 **Cr** Chromium 52.0	25 **Mn** Manganese 54.9	26 **Fe** Iron 55.8	27 **Co** Cobalt 58.9	28 **Ni** Nickel 58.7	29 **Cu** Copper 63.5	30 **Zn** Zinc 65.4	31 **Ga** Gallium 69.7	32 **Ge** Germanium 72.6	33 **As** Arsenic 74.9	34 **Se** Selenium 79.0	35 **Br** Bromine 79.9	36 **Kr** Krypton 83.8
37 **Rb** Rubidium 85.5	38 **Sr** Strontium 87.6	39 **Y** Yttrium 88.9	40 **Zr** Zirconium 91.2	41 **Nb** Niobium 92.9	42 **Mo** Molybdenum 95.9	43 **Tc** Technetium (98)	44 **Ru** Ruthenium 101.1	45 **Rh** Rhodium 102.9	46 **Pd** Palladium 106.4	47 **Ag** Silver 107.9	48 **Cd** Cadmium 112.4	49 **In** Indium 114.8	50 **Sn** Tin 118.7	51 **Sb** Antimony 121.8	52 **Te** Tellurium 127.6	53 **I** Iodine 126.9	54 **Xe** Xenon 131.3
55 **Cs** Cesium 132.9	56 **Ba** Barium 137.3	57 **La** Lanthanum 138.9	72 **Hf** Hafnium 178.5	73 **Ta** Tantalum 180.9	74 **W** Tungsten 183.8	75 **Re** Rhenium 186.2	76 **Os** Osmium 190.2	77 **Ir** Iridium 192.2	78 **Pt** Platinum 195.1	79 **Au** Gold 197.0	80 **Hg** Mercury 200.6	81 **Tl** Thallium 204.4	82 **Pb** Lead 207.2	83 **Bi** Bismuth 209.0	84 **Po** Polonium (209)	85 **At** Astatine (210)	86 **Rn** Radon (222)
87 **Fr** Francium (223)	88 **Ra** Radium (226)	89 **Ac** Actinium (227)	104 **Rf** Rutherfordium (261)	105 **Db** Dubnium (262)	106 **Sg** Seaborgium (263)	107 **Bh** Bohrium (262)	108 **Hs** Hassium (265)	109 **Mt** Meitnerium (266)									

14 **Si** Silicon 28.1 — Atomic Number, Symbol, Name, Atomic Mass

58	59	60	61	62	63	64	65	66	67	68	69	70	71
Ce Cerium 140.1	**Pr** Praseodymium 140.9	**Nd** Neodymium 144.2	**Pm** Promethium (145)	**Sm** Samarium 150.4	**Eu** Europium 152.0	**Gd** Gadolinium 157.3	**Tb** Terbium 158.9	**Dy** Dysprosium 162.5	**Ho** Holmium 164.9	**Er** Erbium 167.3	**Tm** Thulium 168.9	**Yb** Ytterbium 173.0	**Lu** Lutetium 175.0
90 **Th** Thorium 232.0	91 **Pa** Protactinium 231.0	92 **U** Uranium 238.0	93 **Np** Neptunium (237)	94 **Pu** Plutonium (244)	95 **Am** Americium (243)	96 **Cm** Curium (247)	97 **Bk** Berkelium (247)	98 **Cf** Californium (251)	99 **Es** Einsteinium (252)	100 **Fm** Fermium (257)	101 **Md** Mendelevium (258)	102 **No** Nobelium (259)	103 **Lr** Lawrencium (262)

Based on mass of C^{12} at 12.00.

Values in parentheses are the masses of the most stable or best known isotopes for elements which do not occur naturally.

ATOMIC MASSES OF THE ELEMENTS

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

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	$C_2O_4^{2-}$	Oxalate
$Cr_2O_7^{2-}$	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_2O_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_2CO_3	8.5×10^{-12}
Silver chloride	$AgCl$	1.8×10^{-10}
Silver chromate	Ag_2CrO_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.

STRENGTH OF ACID: STRONG (top) → WEAK (bottom)

STRENGTH OF BASE: WEAK (top) → STRONG (bottom)

Name of Acid	Acid		Base	K_a
Perchloric	$HClO_4$	$\rightarrow$	$H^+ + ClO_4^-$	very large
Hydriodic	HI	$\rightarrow$	$H^+ + I^-$	very large
Hydrobromic	HBr	$\rightarrow$	$H^+ + Br^-$	very large
Hydrochloric	HCl	$\rightarrow$	$H^+ + Cl^-$	very large
Nitric	HNO_3	$\rightarrow$	$H^+ + NO_3^-$	very large
Sulphuric	H_2SO_4	$\rightarrow$	$H^+ + HSO_4^-$	very large
Hydronium Ion	H_3O^+	$\rightleftarrows$	$H^+ + H_2O$	1.0
Iodic	HIO_3	$\rightleftarrows$	$H^+ + IO_3^-$	1.7×10^{-1}
Oxalic	$H_2C_2O_4$	$\rightleftarrows$	$H^+ + HC_2O_4^-$	5.9×10^{-2}
Sulphurous $(SO_2 + H_2O)$	H_2SO_3	$\rightleftarrows$	$H^+ + HSO_3^-$	1.5×10^{-2}
Hydrogen sulphate ion	HSO_4^-	$\rightleftarrows$	$H^+ + SO_4^{2-}$	1.2×10^{-2}
Phosphoric	H_3PO_4	$\rightleftarrows$	$H^+ + H_2PO_4^-$	7.5×10^{-3}
Hexaaquoiron ion, iron(III) ion	$Fe(H_2O)_6^{3+}$	$\rightleftarrows$	$H^+ + Fe(H_2O)_5(OH)^{2+}$	6.0×10^{-3}
Citric	$H_3C_6H_5O_7$	$\rightleftarrows$	$H^+ + H_2C_6H_5O_7^-$	7.1×10^{-4}
Nitrous	HNO_2	$\rightleftarrows$	$H^+ + NO_2^-$	4.6×10^{-4}
Hydrofluoric	HF	$\rightleftarrows$	$H^+ + F^-$	3.5×10^{-4}
Methanoic, formic	$HCOOH$	$\rightleftarrows$	$H^+ + HCOO^-$	1.8×10^{-4}
Hexaaquochromium ion, chromium(III) ion	$Cr(H_2O)_6^{3+}$	$\rightleftarrows$	$H^+ + Cr(H_2O)_5(OH)^{2+}$	1.5×10^{-4}
Benzoic	C_6H_5COOH	$\rightleftarrows$	$H^+ + C_6H_5COO^-$	6.5×10^{-5}
Hydrogen oxalate ion	$HC_2O_4^-$	$\rightleftarrows$	$H^+ + C_2O_4^{2-}$	6.4×10^{-5}
Ethanoic, acetic	CH_3COOH	$\rightleftarrows$	$H^+ + CH_3COO^-$	1.8×10^{-5}
Dihydrogen citrate ion	$H_2C_6H_5O_7^-$	$\rightleftarrows$	$H^+ + HC_6H_5O_7^{2-}$	1.7×10^{-5}
Hexaaquoaluminum ion, aluminum ion	$Al(H_2O)_6^{3+}$	$\rightleftarrows$	$H^+ + Al(H_2O)_5(OH)^{2+}$	1.4×10^{-5}
Carbonic $(CO_2 + H_2O)$	H_2CO_3	$\rightleftarrows$	$H^+ + HCO_3^-$	4.3×10^{-7}
Monohydrogen citrate ion	$HC_6H_5O_7^{2-}$	$\rightleftarrows$	$H^+ + C_6H_5O_7^{3-}$	4.1×10^{-7}
Hydrogen sulphite ion	HSO_3^-	$\rightleftarrows$	$H^+ + SO_3^{2-}$	1.0×10^{-7}
Hydrogen sulphide	H_2S	$\rightleftarrows$	$H^+ + HS^-$	9.1×10^{-8}
Dihydrogen phosphate ion	$H_2PO_4^-$	$\rightleftarrows$	$H^+ + HPO_4^{2-}$	6.2×10^{-8}
Boric	H_3BO_3	$\rightleftarrows$	$H^+ + H_2BO_3^-$	7.3×10^{-10}
Ammonium ion	NH_4^+	$\rightleftarrows$	$H^+ + NH_3$	5.6×10^{-10}
Hydrocyanic	HCN	$\rightleftarrows$	$H^+ + CN^-$	4.9×10^{-10}
Phenol	C_6H_5OH	$\rightleftarrows$	$H^+ + C_6H_5O^-$	1.3×10^{-10}
Hydrogen carbonate ion	HCO_3^-	$\rightleftarrows$	$H^+ + CO_3^{2-}$	5.6×10^{-11}
Hydrogen peroxide	H_2O_2	$\rightleftarrows$	$H^+ + HO_2^-$	2.4×10^{-12}
Monohydrogen phosphate ion	HPO_4^{2-}	$\rightleftarrows$	$H^+ + PO_4^{3-}$	2.2×10^{-13}
Water	H_2O	$\rightleftarrows$	$H^+ + OH^-$	1.0×10^{-14}
Hydroxide ion	OH^-	$\leftarrow$	$H^+ + O^{2-}$	very small
Ammonia	NH_3	$\leftarrow$	$H^+ + NH_2^-$	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)
$F_{2(g)} + 2e^-$	⇄	$2F^-$	+2.87
$S_2O_8^{2-} + 2e^-$	⇄	$2SO_4^{2-}$	+2.01
$H_2O_2 + 2H^+ + 2e^-$	⇄	$2H_2O$	+1.78
$MnO_4^- + 8H^+ + 5e^-$	⇄	$Mn^{2+} + 4H_2O$	+1.51
$Au^{3+} + 3e^-$	⇄	$Au_{(s)}$	+1.50
$BrO_3^- + 6H^+ + 5e^-$	⇄	$\frac{1}{2}Br_{2(\ell)} + 3H_2O$	+1.48
$ClO_4^- + 8H^+ + 8e^-$	⇄	$Cl^- + 4H_2O$	+1.39
$Cl_{2(g)} + 2e^-$	⇄	$2Cl^-$	+1.36
$Cr_2O_7^{2-} + 14H^+ + 6e^-$	⇄	$2Cr^{3+} + 7H_2O$	+1.23
$\frac{1}{2}O_{2(g)} + 2H^+ + 2e^-$	⇄	H_2O	+1.23
$MnO_{2(s)} + 4H^+ + 2e^-$	⇄	$Mn^{2+} + 2H_2O$	+1.22
$IO_3^- + 6H^+ + 5e^-$	⇄	$\frac{1}{2}I_{2(s)} + 3H_2O$	+1.20
$Br_{2(\ell)} + 2e^-$	⇄	$2Br^-$	+1.09
$AuCl_4^- + 3e^-$	⇄	$Au_{(s)} + 4Cl^-$	+1.00
$NO_3^- + 4H^+ + 3e^-$	⇄	$NO_{(g)} + 2H_2O$	+0.96
$Hg^{2+} + 2e^-$	⇄	$Hg_{(\ell)}$	+0.85
$\frac{1}{2}O_{2(g)} + 2H^+(10^{-7}\,M) + 2e^-$	⇄	H_2O	+0.82
$2NO_3^- + 4H^+ + 2e^-$	⇄	$N_2O_4 + 2H_2O$	+0.80
$Ag^+ + e^-$	⇄	$Ag_{(s)}$	+0.80
$\frac{1}{2}Hg_2^{2+} + e^-$	⇄	$Hg_{(\ell)}$	+0.80
$Fe^{3+} + e^-$	⇄	Fe^{2+}	+0.77
$O_{2(g)} + 2H^+ + 2e^-$	⇄	H_2O_2	+0.70
$MnO_4^- + 2H_2O + 3e^-$	⇄	$MnO_{2(s)} + 4OH^-$	+0.60
$I_{2(s)} + 2e^-$	⇄	$2I^-$	+0.54
$Cu^+ + e^-$	⇄	$Cu_{(s)}$	+0.52
$H_2SO_3 + 4H^+ + 4e^-$	⇄	$S_{(s)} + 3H_2O$	+0.45
$Cu^{2+} + 2e^-$	⇄	$Cu_{(s)}$	+0.34
$SO_4^{2-} + 4H^+ + 2e^-$	⇄	$H_2SO_3 + H_2O$	+0.17
$Cu^{2+} + e^-$	⇄	Cu^+	+0.15
$Sn^{4+} + 2e^-$	⇄	Sn^{2+}	+0.15
$S_{(s)} + 2H^+ + 2e^-$	⇄	$H_2S_{(g)}$	+0.14
$2H^+ + 2e^-$	⇄	$H_{2(g)}$	+0.00
$Pb^{2+} + 2e^-$	⇄	$Pb_{(s)}$	−0.13
$Sn^{2+} + 2e^-$	⇄	$Sn_{(s)}$	−0.14
$Ni^{2+} + 2e^-$	⇄	$Ni_{(s)}$	−0.26
$H_3PO_4 + 2H^+ + 2e^-$	⇄	$H_3PO_3 + H_2O$	−0.28
$Co^{2+} + 2e^-$	⇄	$Co_{(s)}$	−0.28
$Se_{(s)} + 2H^+ + 2e^-$	⇄	H_2Se	−0.40
$Cr^{3+} + e^-$	⇄	Cr^{2+}	−0.41
$2H_2O + 2e^-$	⇄	$H_2 + 2OH^-(10^{-7}\,M)$	−0.41
$Fe^{2+} + 2e^-$	⇄	$Fe_{(s)}$	−0.45
$Ag_2S_{(s)} + 2e^-$	⇄	$2Ag_{(s)} + S^{2-}$	−0.69
$Cr^{3+} + 3e^-$	⇄	$Cr_{(s)}$	−0.74
$Zn^{2+} + 2e^-$	⇄	$Zn_{(s)}$	−0.76
$Te_{(s)} + 2H^+ + 2e^-$	⇄	H_2Te	−0.79
$2H_2O + 2e^-$	⇄	$H_{2(g)} + 2OH^-$	−0.83
$Mn^{2+} + 2e^-$	⇄	$Mn_{(s)}$	−1.19
$Al^{3+} + 3e^-$	⇄	$Al_{(s)}$	−1.66
$Mg^{2+} + 2e^-$	⇄	$Mg_{(s)}$	−2.37
$Na^+ + e^-$	⇄	$Na_{(s)}$	−2.71
$Ca^{2+} + 2e^-$	⇄	$Ca_{(s)}$	−2.87
$Sr^{2+} + 2e^-$	⇄	$Sr_{(s)}$	−2.89
$Ba^{2+} + 2e^-$	⇄	$Ba_{(s)}$	−2.91
$K^+ + e^-$	⇄	$K_{(s)}$	−2.93
$Rb^+ + e^-$	⇄	$Rb_{(s)}$	−2.98
$Cs^+ + e^-$	⇄	$Cs_{(s)}$	−3.03
$Li^+ + e^-$	⇄	$Li_{(s)}$	−3.04

Overpotential Effect

Overpotential Effect

STRONG ↑ STRENGTH OF OXIDIZING AGENT ↓ WEAK

WEAK ↑ STRENGTH OF REDUCING AGENT ↓ STRONG