INSERT STUDENT I.D. NUMBER (PEN)

STICKER IN THIS SPACE

APRIL 2000

PROVINCIAL EXAMINATION

MINISTRY OF EDUCATION

CHEMISTRY 12

GENERAL INSTRUCTIONS

1. Insert the stickers with your Student I.D. Number (PEN) in the allotted spaces above and on the **back** cover of this booklet. **Under no circumstance is your name or identification, other than your Student I.D. 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. 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.

5. For each of the written-response questions, write your answer in the space provided in this booklet.

6. 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.

7. 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.

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CHEMISTRY 12 PROVINCIAL EXAMINATION

		Value	Suggested Time
1. This examination consists of **two** parts:			
PART A:	48 multiple-choice questions	48	70
PART B:	12 written-response questions	32	50
	Total:	**80 marks**	**120 minutes**

2. Aside from an approved calculator, electronic devices, including dictionaries and pagers, are **not** permitted in the examination room.

3. 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.

4. **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.

5. 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.

6. This examination is designed to be completed in **two hours**. *Students may, however, take up to 30 minutes of additional time to finish.*

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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. At 25°C, which of the following reactions is fastest?

   A. $H_{2(g)} + I_{2(g)} \rightarrow 2HI_{(g)}$

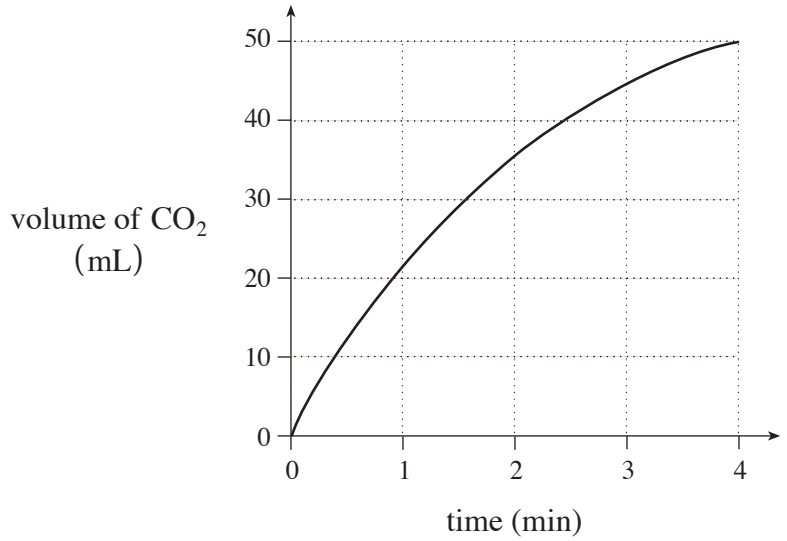
   B. $Ag^{+}_{(aq)} + I^{-}_{(aq)} \rightarrow AgI_{(s)}$

   C. $C_6H_{12}O_{6(s)} + 6\,O_{2(g)} \rightarrow 6CO_{2(g)} + 6H_2O_{(g)}$

   D. $5C_2O_4{}^{2-}_{(aq)} + 2MnO_4{}^{-}_{(aq)} + 16H^{+}_{(aq)} \rightarrow 10CO_{2(g)} + 2Mn^{2+}_{(aq)} + 8H_2O_{(\ell)}$

2. Consider the graph for the following reaction:

$$CaCO_{3(s)} + 2HCl_{(aq)} \rightarrow CaCl_{2(aq)} + CO_{2(g)} + H_2O_{(\ell)}$$



The average rate of reaction is greatest in the time interval

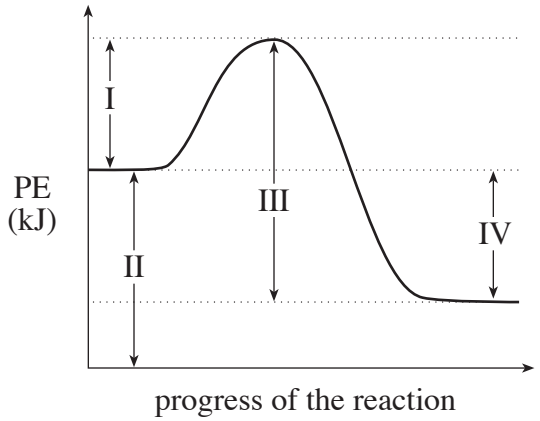
A. 0 – 1 minute.
B. 0 – 2 minutes.
C. 0 – 3 minutes.
D. 0 – 4 minutes.

OVER

3. Which of the following changes will increase the average kinetic energy of reactant molecules?

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

4. Consider the following potential energy diagram:



   Which of the following represents the heat of reaction, ΔH, for the forward reaction?

   A. I
   B. II
   C. III
   D. IV

5. When a catalyst is added to a reaction

I.	the heat of reaction increases
II.	a new mechanism is provided
III.	the equilibrium constant increases

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

6. Consider the following mechanism for a reaction:

Step 1	$HBr + O_2 \rightarrow HOOBr$
Step 2	$HBr + HOOBr \rightarrow 2HOBr$
Step 3	$2HBr + 2HOBr \rightarrow 2H_2O + 2Br_2$

Which of the following statements is correct?

A. Br_2 is a reactant.
B. HBr is a product.
C. HOBr is a catalyst.
D. HOOBr is a reaction intermediate.

7. Which of the following applies to a chemical equilibrium?

I.	Forward and reverse reaction rates are equal
II.	Equilibrium can be achieved from either direction
III.	Macroscopic properties are constant

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

8. In which of the following will the driving forces of minimum enthalpy and maximum entropy oppose one another?

A. $2C_{(s)} + O_{2(g)} \rightarrow 2CO_{(g)}$ $\Delta H = -221\,kJ$
B. $2N_{2(g)} + O_{2(g)} \rightarrow 2N_2O_{(g)}$ $\Delta H = +164\,kJ$
C. $2CO_{(g)} + O_{2(g)} \rightarrow 2CO_{2(g)}$ $\Delta H = -566\,kJ$
D. $4CO_{2(g)} + 6H_2O_{(g)} \rightarrow 2C_2H_{6(g)} + 7O_{2(g)}$ $\Delta H = +3122\,kJ$

OVER

9. Consider the following equilibrium:

$$\underset{\text{(yellow)}}{2CrO_4^{2-}{}_{(aq)}} + 2H_3O^+{}_{(aq)} \rightleftarrows \underset{\text{(orange)}}{Cr_2O_7^{2-}{}_{(aq)}} + 3H_2O_{(\ell)}$$

An unknown solution is added to an orange equilibrium sample until the sample turns yellow. The unknown solution could be

A. KNO_3

B. $NaOH$

C. NH_4NO_3

D. CH_3COOH

10. Ammonia, NH_3, is produced by the following reaction:

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

Which of the following would result in the highest concentration of ammonia at equilibrium?

A. increasing the temperature and increasing the pressure
B. decreasing the temperature and increasing the pressure
C. increasing the temperature and decreasing the pressure
D. decreasing the temperature and decreasing the pressure

11. What is the K_{eq} expression for the following reaction?

$$SnO_{2(s)} + 2CO_{(g)} \rightleftarrows Sn_{(s)} + 2CO_{2(g)}$$

A. $K_{eq} = \dfrac{[CO_2]}{[CO]}$

B. $K_{eq} = \dfrac{[CO_2]^2}{[CO]^2}$

C. $K_{eq} = \dfrac{[Sn][CO_2]^2}{[CO]^2}$

D. $K_{eq} = \dfrac{[Sn][CO_2]^2}{[SnO_2][CO]^2}$

12. Consider the following reaction:

$$C_{(s)} + 2H_{2(g)} \rightleftarrows CH_{4(g)} \qquad \Delta H = -74.8\,kJ$$

Which of the following will cause an increase in the value of K_{eq}?

A. increasing $[H_2]$
B. decreasing the volume
C. finely powdering the $C_{(s)}$
D. decreasing the temperature

13. Consider the following equilibrium:

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

At equilibrium $[H_2] = 0.00220\,mol/L$, $[I_2] = 0.00220\,mol/L$ and $[HI] = 0.0156\,mol/L$. The value of K_{eq} is

A. 3.10×10^{-4}
B. 1.99×10^{-2}
C. 5.03×10^{1}
D. 3.22×10^{3}

14. Which of the following will dissolve in water to produce a molecular solution?

A. $CaCl_2$
B. $NaOH$
C. CH_3OH
D. $Sr(OH)_2$

15. In a solubility equilibrium, the

A. rate of dissolving equals the rate of crystallization.
B. neither dissolving nor crystallization are occurring.
C. concentration of solute and solvent are always equal.
D. mass of dissolved solute is greater than the mass of the solution.

OVER

16. Which of the following solutions would have $\left[Fe^{3+}\right] = 0.020\,M$?

A. $0.40\,L$ of $0.050\,M$ $Fe(NO_3)_3$

B. $0.80\,L$ of $0.020\,M$ $Fe_2(SO_4)_3$

C. $0.50\,L$ of $0.040\,M$ $FeC_6H_5O_7$

D. $0.50\,L$ of $0.010\,M$ $Fe_2(C_2O_4)_3$

17. Which of the following substances has the lowest solubility?

A. BaS
B. CuS
C. FeS
D. ZnS

18. The complete ionic equation for the reaction between MgS and $Sr(OH)_2$ is

A. $MgS_{(aq)} + Sr(OH)_{2(aq)} \rightarrow Mg(OH)_{2(s)} + SrS_{(s)}$

B. $MgS_{(aq)} + Sr(OH)_{2(aq)} \rightarrow Mg(OH)_{2(s)} + SrS_{(aq)}$

C. $Mg^{2+}_{(aq)} + S^{2-}_{(aq)} + Sr^{2+}_{(aq)} + 2OH^{-}_{(aq)} \rightarrow Mg^{2+}_{(aq)} + 2OH^{-}_{(aq)} + SrS_{(s)}$

D. $Mg^{2+}_{(aq)} + S^{2-}_{(aq)} + Sr^{2+}_{(aq)} + 2OH^{-}_{(aq)} \rightarrow Mg(OH)_{2(s)} + Sr^{2+}_{(aq)} + S^{2-}_{(aq)}$

19. Consider the following equilibrium:

$$Fe(OH)_{2(s)} \rightleftarrows Fe^{2+}_{(aq)} + 2OH^{-}_{(aq)}$$

Which of the following will cause the equilibrium to shift to the right?

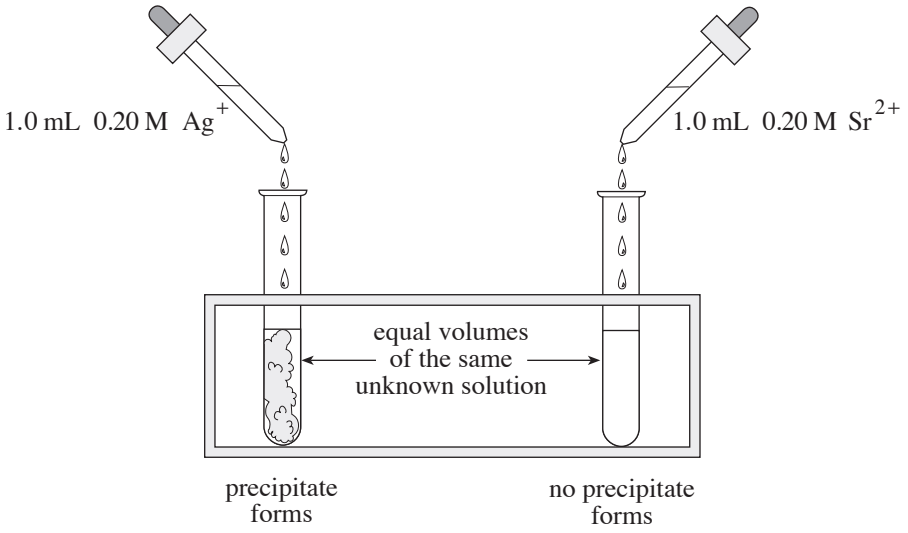
A. adding KOH

B. adding Na_2S

C. adding $Fe(OH)_2$

D. adding $Fe(NO_3)_2$

20. Consider the following experiment:



The unknown solution could contain

A. 0.20 M OH^-
B. 0.20 M NO_3^-
C. 0.20 M PO_4^{3-}
D. 0.20 M SO_4^{2-}

21. A compound has a solubility of 7.1×10^{-5} M at 25°C. The compound is

A. CuS
B. AgBr
C. $CaCO_3$
D. $CaSO_4$

22. Consider the following reaction:

$$H_3BO_{3(aq)} + HS^-_{(aq)} \rightleftarrows H_2BO_3^-{}_{(aq)} + H_2S_{(aq)}$$

The order of Brønsted-Lowry acids and bases in this equation is

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

OVER

23. The conjugate base of an acid is produced by

A. adding a proton to the acid.
B. adding an electron to the acid.
C. removing a proton from the acid.
D. removing an electron from the acid.

24. Which of the following represents the predominant reaction between HCO_3^- and water?

A. $2HCO_3^- \rightarrow H_2O + 2CO_2$
B. $HCO_3^- + H_2O \rightarrow H_2CO_3 + OH^-$
C. $HCO_3^- + H_2O \rightarrow H_3O^+ + CO_3^{2-}$
D. $2HCO_3^- + H_2O \rightarrow H_3O^+ + CO_3^{2-} + OH^- + CO_2$

25. Water acts as an acid when it reacts with which of the following?

I.	CN^-
II.	NH_3
III.	$HClO_4$
IV.	CH_3COO^-

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

26. In a solution of 0.10 M H_2SO_4, the ions present in order of decreasing concentration are

A. $[H_3O^+] > [HSO_4^-] > [SO_4^{2-}] > [OH^-]$
B. $[H_3O^+] > [SO_4^{2-}] > [HSO_4^-] > [OH^-]$
C. $[OH^-] > [SO_4^{2-}] > [HSO_4^-] > [H_3O^+]$
D. $[SO_4^{2-}] > [HSO_4^-] > [OH^-] > [H_3O^+]$

27. Consider the following equilibrium:

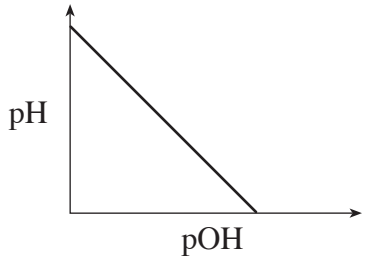
$$2H_2O_{(\ell)} + \text{energy} \rightleftarrows H_3O^+_{(aq)} + OH^-_{(aq)}$$

What will cause the pH to increase and the K_w to decrease?

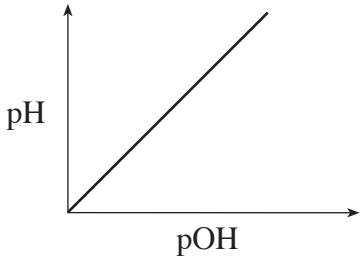
A. adding a strong acid
B. adding a strong base
C. increasing the temperature
D. decreasing the temperature

28. Which of the following graphs describes the relationship between pH and pOH?

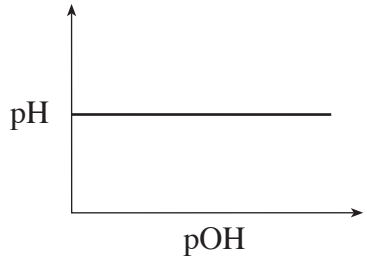
A.



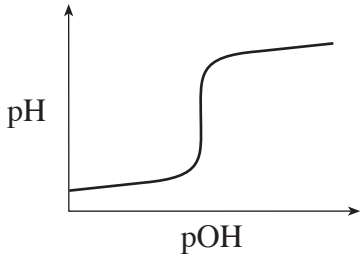
B.



C.



D.



29. The relationship $\frac{[H_3BO_3][OH^-]}{[H_2BO_3^-]}$ is the expression for

A. K_a for H_3BO_3
B. K_b for H_3BO_3
C. K_a for $H_2BO_3^-$
D. K_b for $H_2BO_3^-$

OVER

30. The value of K_b for $H_2PO_4^-$ is

A. 1.3×10^{-12}
B. 6.2×10^{-8}
C. 1.6×10^{-7}
D. 7.5×10^{-3}

31. Which of the following solutions has a pH less than 7.00?

A. NaCl
B. LiOH
C. NH_4NO_3
D. KCH_3COO

32. Which of the following will form a basic aqueous solution?

A. HSO_3^-
B. HSO_4^-
C. HPO_4^{2-}
D. $HC_2O_4^-$

33. What is the approximate K_a value for the indicator chlorophenol red?

A. 1×10^{-14}
B. 1×10^{-8}
C. 1×10^{-6}
D. 1×10^{-3}

34. What is the pH of the solution formed when 0.040 mol $NaOH_{(s)}$ is added to 2.00 L of 0.020 M HCl?

A. 0.00
B. 1.40
C. 1.70
D. 7.00

35. Which of the following titrations will always have an equivalence point at a pH > 7.00?

A. weak acid with a weak base
B. strong acid with a weak base
C. weak acid with a strong base
D. strong acid with a strong base

36. A buffer solution may contain equal moles of

A. weak acid and strong base.
B. strong acid and strong base.
C. weak acid and its conjugate base.
D. strong acid and its conjugate base.

37. A gas which is produced by burning coal and also contributes to the formation of acid rain is

A. H_2
B. O_3
C. SO_2
D. C_3H_8

38. Manganese has an oxidation number of +4 in

A. MnO
B. MnO_2
C. Mn_2O_3
D. Mn_2O_7

39. In which reaction is nitrogen reduced?

A. $2NO + O_2 \rightarrow 2NO_2$
B. $4NH_3 + 5O_2 \rightarrow 4NO + 6H_2O$
C. $Cu^{2+} + 2NO_2 + 2H_2O \rightarrow Cu + 4H^+ + 2NO_3^-$
D. $4Zn + 10\,H^+ + NO_3^- \rightarrow 4Zn^{2+} + NH_4^+ + 3H_2O$

OVER

40. An oxidizing agent will cause which of the following changes?

A. $PtO_2 \rightarrow PtO$

B. $PtO_3 \rightarrow PtO_2$

C. $Pt(OH)_2 \rightarrow Pt$

D. $Pt(OH)_2^{2+} \rightarrow PtO_3$

41. Consider the overall reaction of the rechargeable nickel-cadmium battery:

$$NiO_{2(s)} + Cd_{(s)} + 2H_2O_{(\ell)} \rightarrow Ni(OH)_{2(s)} + Cd(OH)_{2(s)}$$

Which of the following occurs at the **anode** as the reaction proceeds?

A. Cd loses $2e^-$ and forms $Cd(OH)_{2(s)}$

B. Cd gains $2e^-$ and forms $Cd(OH)_{2(s)}$

C. NiO_2 loses $2e^-$ and forms $Ni(OH)_{2(s)}$

D. NiO_2 gains $2e^-$ and forms $Ni(OH)_{2(s)}$

42. Which of the following will oxidize Fe^{2+} ?

A. $I_{2(s)}$

B. $Ni_{(s)}$

C. $Zn_{(s)}$

D. $Br_{2(\ell)}$

43. Consider the following half-reaction in a basic solution:

$$Ag_2O_3 \rightarrow AgO \qquad \text{(basic)}$$

The balanced half-reaction is

A. $Ag_2O_3 + 4H^+ + 4e^- \rightarrow AgO + 2H_2O$

B. $Ag_2O_3 + 2H^+ + 2e^- \rightarrow 2AgO + H_2O$

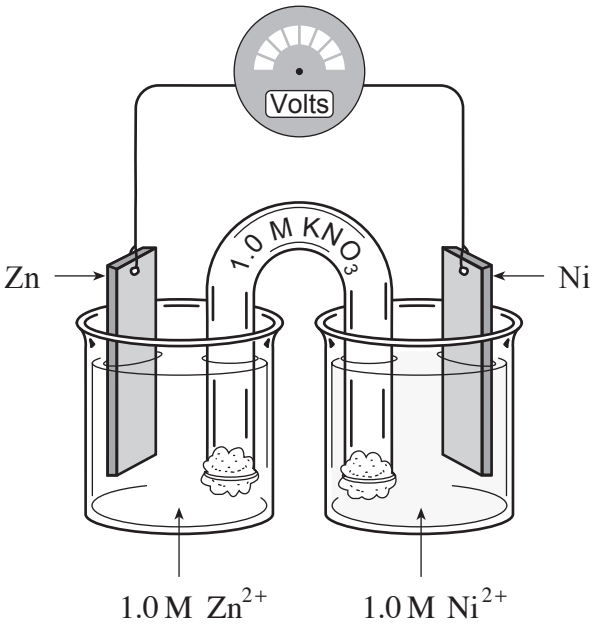
C. $Ag_2O_3 + H_2O + 2e^- \rightarrow 2AgO + 2OH^-$

D. $Ag_2O_3 + 2H_2O + 4e^- \rightarrow AgO + 4OH^-$

44. The concentration of $Fe^{2+}_{(aq)}$ can be determined by a redox titration using

A. KBr
B. $SnCl_2$
C. $KMnO_4$ (basic)
D. $KBrO_3$ (acidic)

45. Consider the following electrochemical cell:



Which of the following occurs as the cell operates?

A. Zinc electrode is reduced and increases in mass.
B. Zinc electrode is reduced and decreases in mass.
C. Zinc electrode is oxidized and increases in mass.
D. Zinc electrode is oxidized and decreases in mass.

46. Which of the following reactants would produce an E° of +0.63 V?

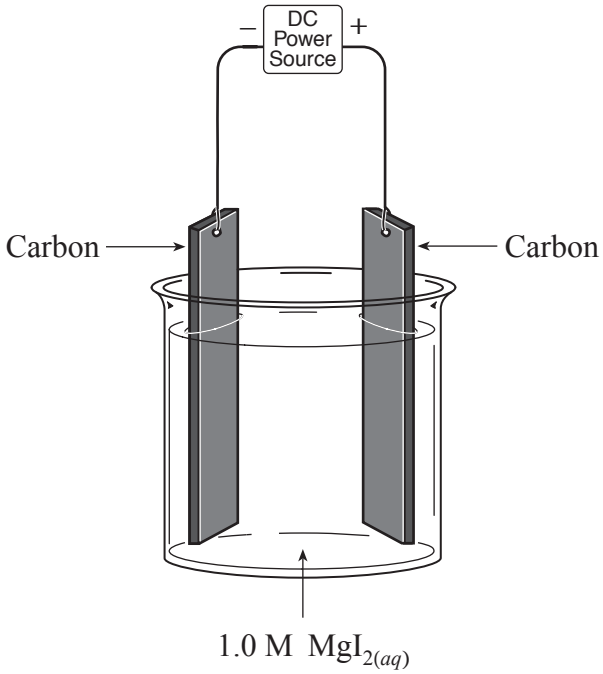
A. $Ag^+ + I_2$
B. $Pb^{2+} + Zn$
C. $Mg^{2+} + Ca$
D. $Zn^{2+} + Mn$

OVER

47. The process of applying an electric current through a cell to produce a chemical change is called

A. corrosion.
B. ionization.
C. hydrolysis.
D. electrolysis.

48. Consider the following electrolytic cell:



The cathode reaction is

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

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

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. Consider the following reaction:

$$Mg_{(s)} + 2HCl_{(aq)} \rightarrow MgCl_{2(aq)} + H_{2(g)}$$

A 0.024 g sample of Mg reacts completely with HCl in 14.0 s. Calculate the average rate of consumption of HCl in mol/s. **(2 marks)**

OVER

2. Using collision theory, give **two** reasons why an increase in temperature results in an increase in reaction rate. **(2 marks)**

i) _____

_____

ii) _____

_____

3. Methanol, CH_3OH, is produced industrially by the following reaction:

$$CO_{(g)} + 2H_{2(g)} \rightleftarrows CH_3OH_{(g)} + \text{heat}$$

a) State **two** different methods of shifting the equilibrium to the right. **(1 mark)**

i) _____

_____

ii) _____

_____

b) In terms of rates, explain why these methods cause the equilibrium to shift to the right. **(1 mark)**

_____

_____

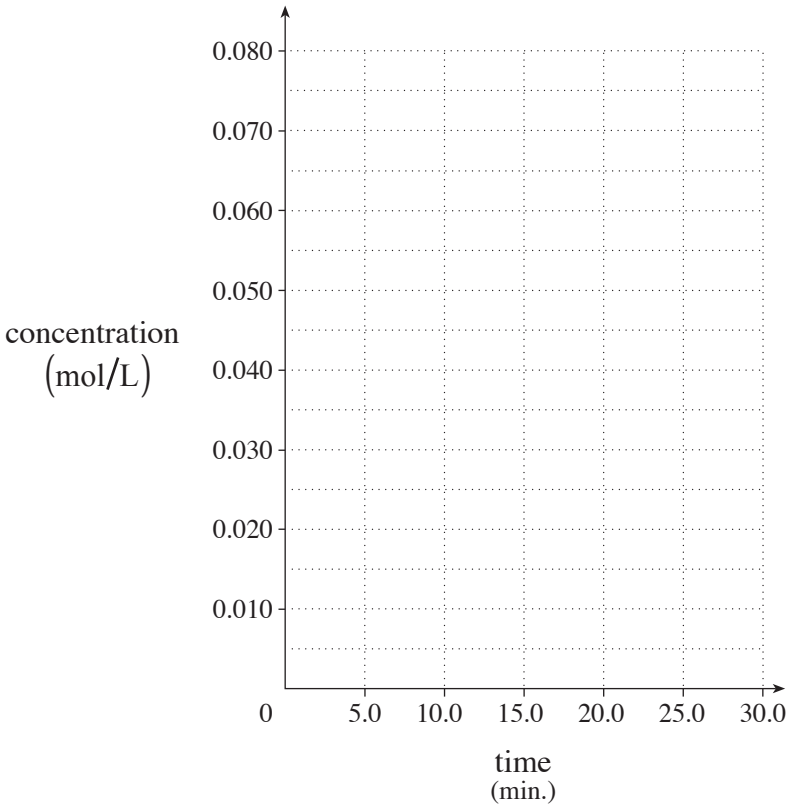
_____

4. Consider the following equilibrium:

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

A 2.0 L container is filled with 0.070 mol of H_2 and 0.060 mol of I_2. Equilibrium is reached after 15.0 minutes at which time there is 0.060 mol of HI present.

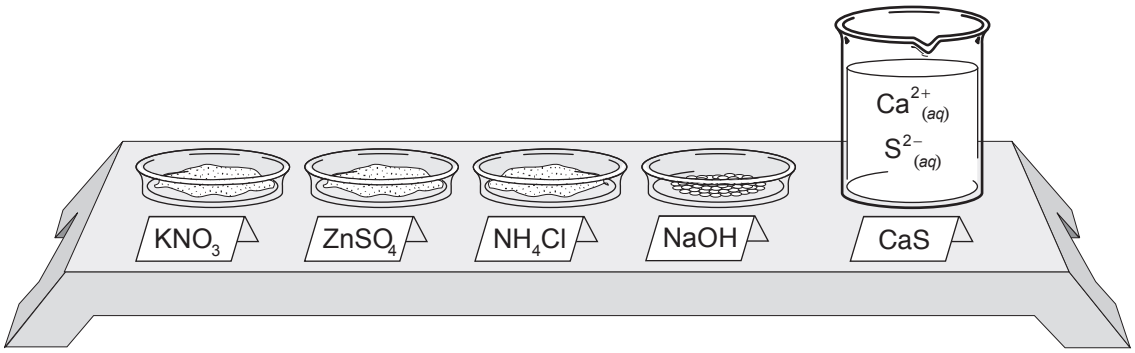
Sketch and label the graphs for the changes in concentrations of H_2, I_2, and HI for the time period of 0 to 30.0 minutes. **(3 marks)**



OVER

5. Calculate the maximum concentration of Pb^{2+} that can exist in 3.0×10^{-2} M Na_2SO_4 without forming a precipitate. **(2 marks)**

6. Consider the following:



a) Which two solid samples could be added to the CaS solution in order to remove first one ion and then the other from the solution. Indicate the order in which to add them. **(2 marks)**

First add: _____

Then add: _____

b) Write the net ionic equation for one of the precipitation reactions in part a). **(1 mark)**

7. A sample of a weak acid was found to conduct an electric current better than a sample of a strong acid. Explain these results in terms of ion concentration. **(2 marks)**

_____

_____

_____

_____

8. Calculate the $\left[OH^{-}\right]$ of $0.10\,M\ NH_3$. **(4 marks)**

OVER

9. A titration was performed by adding $0.175\,M\ H_2C_2O_4$ to a $25.00\,mL$ sample of $NaOH$. The following data was collected:

	Trial #1	Trial #2	Trial #3
Final volume of $H_2C_2O_4$ (mL)	23.00	39.05	20.95
Initial volume of $H_2C_2O_4$ (mL)	4.85	23.00	5.00

a) Calculate the $[NaOH]$. **(3 marks)**

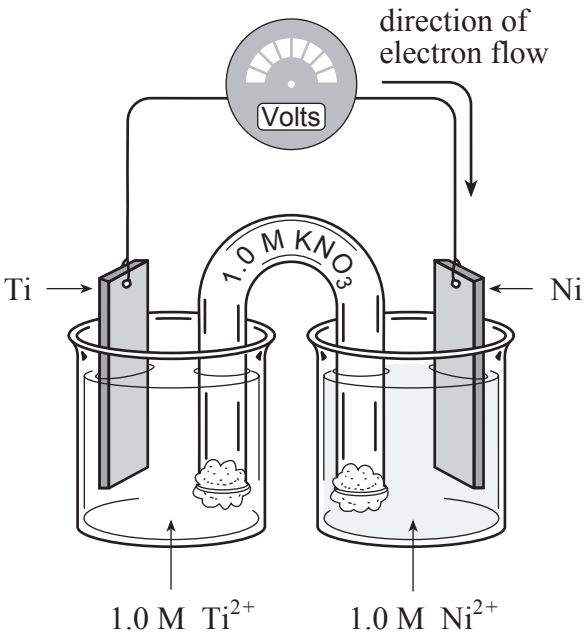
b) Explain why the pH at the equivalence point is greater than 7. **(1 mark)**

10. Balance the following redox reaction in a basic solution. **(4 marks)**

$$As \rightarrow AsH_3 + H_2AsO_4^- \qquad \text{(basic)}$$

OVER

11. Consider the following electrochemical cell:



E° cell = 1.37 V

a) Write the equation for the half-reaction that occurs at the anode. **(1 mark)**

b) Calculate the reduction potential of Ti^{2+}. **(1 mark)**

12. Consider the following reaction for the formation of rust:

$$Fe_{(s)} + \tfrac{1}{2}O_{2(g)} + H_2O_{(\ell)} \rightarrow Fe(OH)_{2(s)}$$

Describe and explain two methods, using different chemical principles, to prevent the formation of rust. **(2 marks)**

i) _____

_____

ii) _____

_____

END OF EXAMINATION

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Question 1:	Question 7:
1. . (2)	7. . (2)
Question 2:	**Question 8:**
2. . (2)	8. . (4)
Question 3:	**Question 9:**
3. . (2)	9. . (4)
Question 4:	**Question 10:**
4. . (3)	10. . (4)
Question 5:	**Question 11:**
5. . (2)	11. . (2)
Question 6:	**Question 12:**
6. . (3)	12. . (2)

Use this space **only** if you have an I.D. sticker.

INSERT STUDENT I.D. NUMBER (PEN)

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CHEMISTRY 12

April 2000

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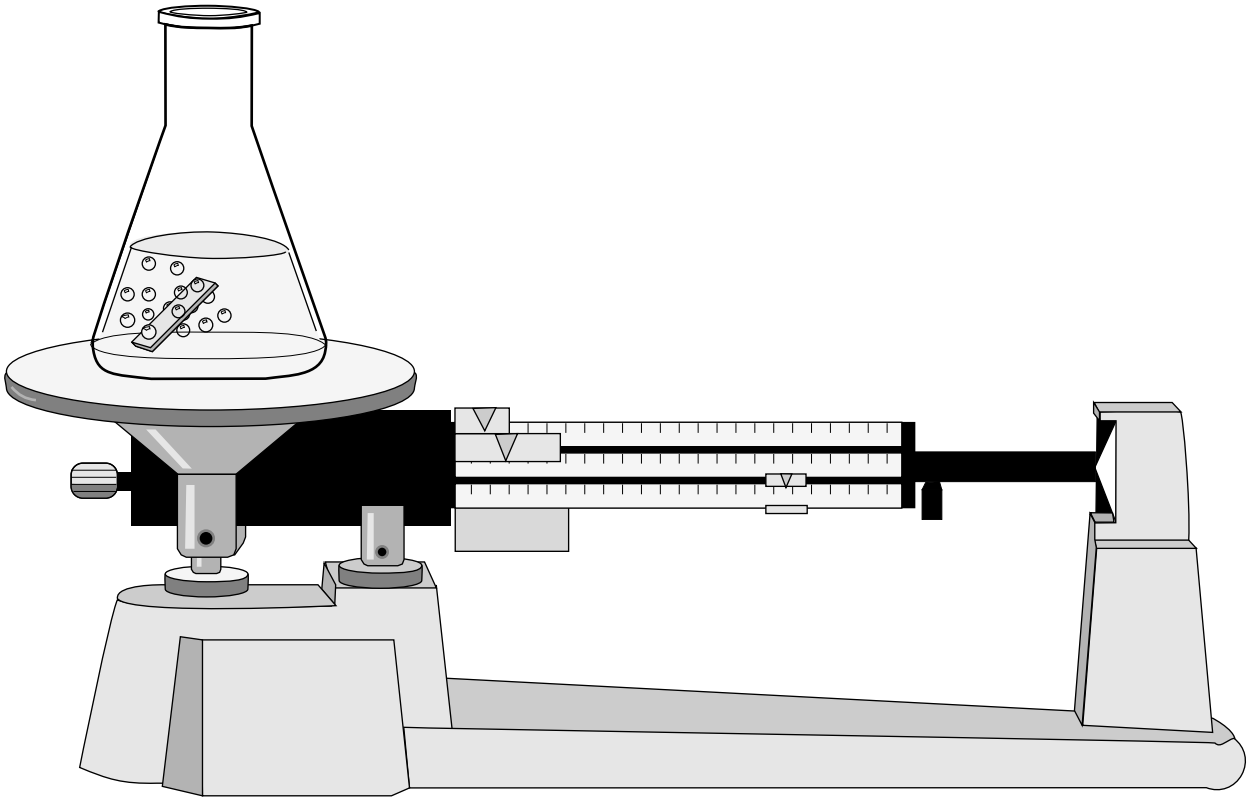

Revised January 2000

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