INSERT STUDENT I.D. NUMBER (PEN)

STICKER IN THIS SPACE

AUGUST 1999

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

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

			Value	**Suggested Time**
	PART A:	48 multiple-choice questions	48	70
	PART B:	11 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 Brönsted-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 support devices such as manuals, printed or electronic cards, printers, memory expansion chips, or external keyboards. Students may have more than one calculator available during the examination, but calculators may not be shared. Communication between calculators is prohibited and calculators 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. The time allotted for this examination is **two hours**.

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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 room temperature, which of the following reactions is fastest?

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

B. $Pb^{2+}{}_{(aq)} + 2I^{-}{}_{(aq)} \rightarrow PbI_{2(s)}$

C. $4Fe_{(s)} + 3O_{2(g)} \rightarrow 2Fe_2O_{3(s)}$

D. $Cu_{(s)} + 2Ag^{+}{}_{(aq)} \rightarrow Cu^{2+}{}_{(aq)} + 2Ag_{(s)}$

2. Consider the following reaction:

$$CH_{4(g)} + 2O_{2(g)} \rightarrow CO_{2(g)} + 2H_2O_{(g)}$$

At a certain temperature, $1.0\,\text{mol}$ CH_4 is consumed in 4.0 minutes.
The rate of production of H_2O is

A. 0.25 mol/min
B. 0.50 mol/min
C. 2.0 mol/min
D. 8.0 mol/min

3. Consider the following reaction in a closed system:

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

Which of the following will cause the rate of the forward reaction to decrease?

A. H_2 is added.

B. A catalyst is added.

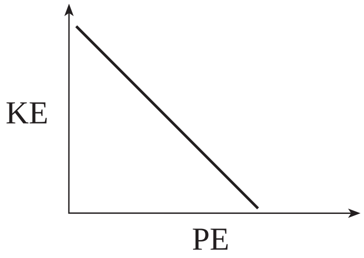
C. The volume is increased.

D. The temperature is increased.

OVER

4. The changes in PE and KE, as reactant molecules approach each other, can be represented by

A.



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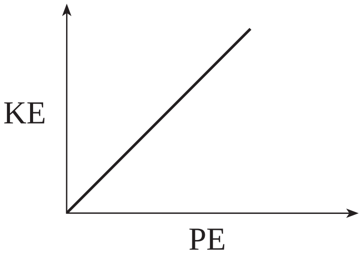

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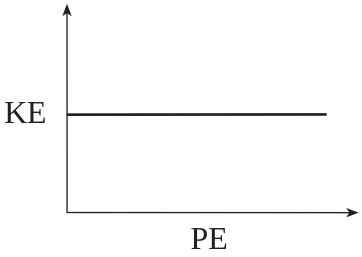

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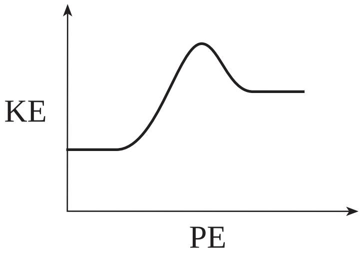
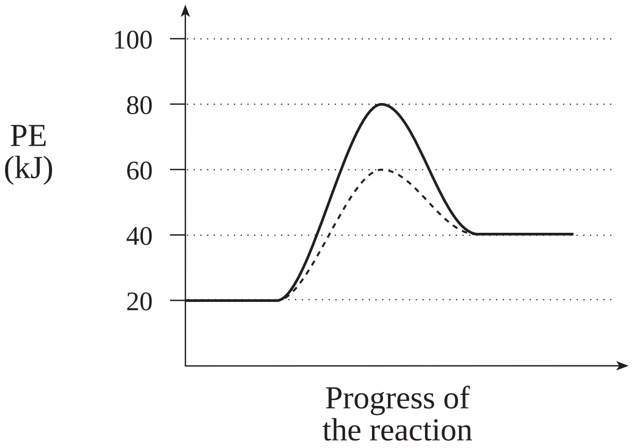


5. Consider the following PE diagram:



Which of the following describes this reaction?

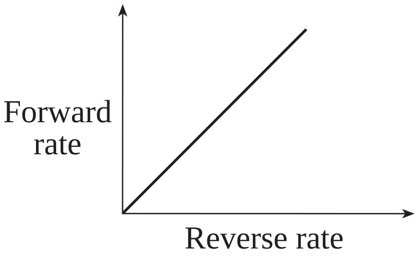
	ΔH (kJ)	ACTIVATION ENERGY (kJ)	REACTION
A.	–20	40	catalyzed
B.	–20	60	catalyzed
C.	+20	40	uncatalyzed
D.	+20	60	uncatalyzed

6. A chemical reaction that gives off energy is

   A. exothermic and ΔH is positive.
   B. exothermic and ΔH is negative.
   C. endothermic and ΔH is positive.
   D. endothermic and ΔH is negative.

7. At different conditions, the relationship between the forward and reverse rates of reaction in an equilibrium system can be represented by

A.



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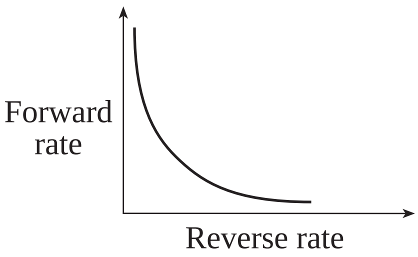

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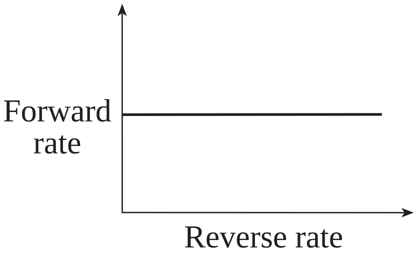
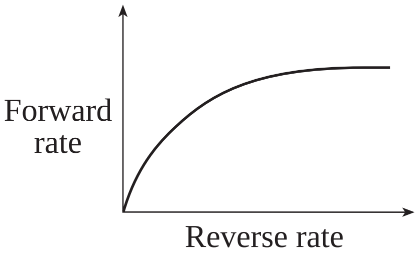


D.



8. Consider the following equilibrium:

$$4NH_{3(g)} + 5O_{2(g)} \rightleftarrows 4NO_{(g)} + 6H_2O_{(g)} + \text{energy}$$

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

   A. adding $H_2O_{(g)}$
   B. removing some $NO_{(g)}$
   C. increasing the volume
   D. decreasing the temperature

9. Consider the following equilibrium:

$$2NO_{(g)} + O_{2(g)} \rightleftarrows 2NO_{2(g)} + \text{energy}$$

When the volume of the container is increased, the equilibrium shifts to the

A. left and K_{eq} decreases.
B. right and K_{eq} increases.
C. left and K_{eq} remains constant.
D. right and K_{eq} remains constant.

10. Consider the following equilibrium:

$$4HCl_{(g)} + O_{2(g)} \rightleftarrows 2H_2O_{(g)} + 2Cl_{2(g)} + \text{energy}$$

The temperature of the equilibrium system is increased and a new equilibrium is established. The rates of the forward and reverse reactions for the new equilibrium compared to the original equilibrium have

	FORWARD RATE	REVERSE RATE
A.	increased	increased
B.	decreased	not changed
C.	decreased	increased
D.	not changed	increased

11. Consider the following reaction:

$$2\,\mathrm{Hg}_{(g)} + \mathrm{O}_{2(g)} \rightleftarrows 2\,\mathrm{HgO}_{(s)}$$

The equilibrium constant expression for the reaction is

A. $\mathrm{K}_{eq} = \dfrac{1}{[\mathrm{Hg}]^2[\mathrm{O}_2]}$

B. $\mathrm{K}_{eq} = [\mathrm{Hg}]^2[\mathrm{O}_2]$

C. $\mathrm{K}_{eq} = \dfrac{[\mathrm{HgO}]^2}{[\mathrm{Hg}]^2[\mathrm{O}_2]}$

D. $\mathrm{K}_{eq} = \dfrac{[2\,\mathrm{HgO}]}{[2\,\mathrm{Hg}][\mathrm{O}_2]}$

12. The value of K_{eq} changes when

A. a catalyst is added.

B. the temperature changes.

C. the surface area changes.

D. the concentration of reactants changes.

13. Consider the following equilibrium:

$$\mathrm{PCl}_{5(g)} \rightleftarrows \mathrm{PCl}_{3(g)} + \mathrm{Cl}_{2(g)}$$

A $1.00\,\mathrm{L}$ flask contains $0.0200\,\mathrm{mol}$ PCl_5, $0.0500\,\mathrm{mol}$ PCl_3 and $0.0500\,\mathrm{mol}$ Cl_2 at equilibrium. The value of K_{eq} is

A. 0.125

B. 2.50

C. 5.00

D. 8.00

OVER

14. Consider the following solutes:

I.	K_3PO_4
II.	C_2H_5OH
III.	$C_{12}H_{22}O_{11}$
IV.	KCH_3COO

Which of the solutes above form only molecular aqueous solutions?

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

15. At a certain temperature, 7.0×10^{-4} mol $MgSO_4$ is present in 100.0 mL of solution. The concentration of the Mg^{2+} in this solution is

A. 7.0×10^{-5} M
B. 7.0×10^{-4} M
C. 7.0×10^{-3} M
D. 7.0×10^{-6} M

16. When equal volumes of 0.20 M $SrBr_2$ and 0.20 M $AgNO_3$ are combined,

A. no precipitate forms.
B. a precipitate of only $AgBr$ forms.
C. a precipitate of only $Sr(NO_3)_2$ forms.
D. precipitates of both $AgBr$ and $Sr(NO_3)_2$ form.

17. Consider the following solubility equilibrium:

$$PbCl_{2(s)} \rightleftarrows Pb^{2+}_{(aq)} + 2Cl^{-}_{(aq)}$$

A student adds $NaCl_{(s)}$ to a saturated solution of $PbCl_2$. When equilibrium is reestablished, how have the concentrations changed from the original equilibrium?

A. $\left[Pb^{2+}\right]$ and $\left[Cl^{-}\right]$ both increased.

B. $\left[Pb^{2+}\right]$ and $\left[Cl^{-}\right]$ both decreased.

C. $\left[Pb^{2+}\right]$ decreased and $\left[Cl^{-}\right]$ increased.

D. $\left[Pb^{2+}\right]$ increased and $\left[Cl^{-}\right]$ decreased.

18. Solid Ag_2CrO_4 is added to water to form a saturated solution.
The K_{sp} value can be calculated by

A. $K_{sp} = \left[CrO_4{}^{2-}\right]^2$

B. $K_{sp} = \left[CrO_4{}^{2-}\right]^3$

C. $K_{sp} = \dfrac{\left[CrO_4{}^{2-}\right]^3}{2}$

D. $K_{sp} = 4\left[CrO_4{}^{2-}\right]^3$

19. Consider the following solubility equilibrium:

$$BaSO_{3(s)} \rightleftarrows Ba^{2+}_{(aq)} + SO_3{}^{2-}_{(aq)}$$

Which of the following will result in an increase of $\left[Ba^{2+}\right]$?

A. adding water

B. adding $BaS_{(s)}$

C. adding $BaSO_{3(s)}$

D. adding $Na_2SO_{3(s)}$

OVER

20. When equal volumes of $0.20\,\text{M}\ \text{Ca}(\text{NO}_3)_2$ and $0.20\,\text{M}\ \text{Na}_2\text{SO}_4$ are combined,

A. a precipitate forms because Trial Ion Product > K_{sp}

B. a precipitate forms because Trial Ion Product < K_{sp}

C. no precipitate forms because Trial Ion Product > K_{sp}

D. no precipitate forms because Trial Ion Product < K_{sp}

21. Solid NaBrO_3 is added to a $0.010\,\text{M}\ \text{Ag}^+$ solution. What is the $[\text{BrO}_3^-]$ when a precipitate first forms?

A. 2.8×10^{-9} M

B. 5.3×10^{-7} M

C. 5.3×10^{-3} M

D. 1.0×10^{-2} M

22. An Arrhenius acid is defined as a chemical species that

A. is a proton donor.
B. is a proton acceptor.
C. produces hydrogen ions in solution.
D. produces hydroxide ions in solution.

23. Consider the acid-base equilibrium system:

$$\text{HC}_2\text{O}_4^- + \text{H}_2\text{BO}_3^- \rightleftarrows \text{H}_3\text{BO}_3 + \text{C}_2\text{O}_4^{2-}$$

Identify the Brönsted-Lowry bases in this equilibrium.

A. H_2BO_3^- and H_3BO_3

B. HC_2O_4^- and H_3BO_3

C. HC_2O_4^- and $\text{C}_2\text{O}_4^{2-}$

D. H_2BO_3^- and $\text{C}_2\text{O}_4^{2-}$

24. An equation representing the reaction of a weak acid with water is

A. $HCl + H_2O \rightarrow H_3O^+ + Cl^-$

B. $NH_3 + H_2O \rightleftarrows NH_4^+ + OH^-$

C. $HCO_3^- + H_2O \rightleftarrows H_2CO_3 + OH^-$

D. $HCOOH + H_2O \rightleftarrows H_3O^+ + HCOO^-$

25. The equilibrium expression for the ion product constant of water is

A. $K_w = \dfrac{[H_3O^+][OH^-]}{[H_2O]}$

B. $K_w = [H_3O^+]^2[O_2]$

C. $K_w = [H_3O^+][OH^-]$

D. $K_w = [H_3O^+]^2[O^{2-}]$

26. Consider the following equilibrium:

$$2H_2O + \text{energy} \rightleftarrows H_3O^+ + OH^-$$

Which of the following describes the result of decreasing the temperature?

	$[H_3O^+]$	$[OH^-]$	K_w
A.	increases	increases	increases
B.	decreases	increases	decreases
C.	increases	decreases	no change
D.	decreases	decreases	decreases

OVER

27. In an acidic solution at $25°\mathrm{C}$,

A. $\left[\mathrm{H_3O^+}\right] < \left[\mathrm{OH^-}\right]$ and $\mathrm{pH} > 7$

B. $\left[\mathrm{H_3O^+}\right] < \left[\mathrm{OH^-}\right]$ and $\mathrm{pH} < 7$

C. $\left[\mathrm{H_3O^+}\right] > \left[\mathrm{OH^-}\right]$ and $\mathrm{pH} > 7$

D. $\left[\mathrm{H_3O^+}\right] > \left[\mathrm{OH^-}\right]$ and $\mathrm{pH} < 7$

28. The pH of a solution changes from 3.00 to 6.00. By what factor does the $\left[\mathrm{H_3O^+}\right]$ change?

A. 2
B. 3
C. 100
D. 1000

29. The K_a expression for the hydrogen sulphite ion, $\mathrm{HSO_3}^-$, is

A. $\mathrm{K}_a = \dfrac{\left[\mathrm{SO_3}^{2-}\right]\left[\mathrm{H_3O^+}\right]}{\left[\mathrm{HSO_3}^-\right]}$

B. $\mathrm{K}_a = \dfrac{\left[\mathrm{H_2SO_3}\right]\left[\mathrm{H_3O^+}\right]}{\left[\mathrm{HSO_3}^-\right]}$

C. $\mathrm{K}_a = \dfrac{\left[\mathrm{SO_3}^{2-}\right]\left[\mathrm{H_3O^+}\right]}{\left[\mathrm{H_2SO_3}\right]}$

D. $\mathrm{K}_a = \dfrac{\left[\mathrm{SO_3}^{2-}\right]\left[\mathrm{H_3O^+}\right]}{\left[\mathrm{HSO_3}^-\right]\left[\mathrm{H_2O}\right]}$

30. The $\left[\mathrm{OH^-}\right]$ in a solution of pH 3.00 is

A. 1.0×10^{-11} M
B. 1.0×10^{-9} M
C. 1.0×10^{-6} M
D. 1.0×10^{-3} M

31. Consider the following equilibrium for an indicator:

$$HInd + H_2O \rightleftarrows H_3O^+ + Ind^-$$

Which two species must be of two different colours in order to be used as an indicator?

A. $HInd$ and H_2O

B. $HInd$ and Ind^-

C. H_3O^+ and Ind^-

D. $HInd$ and H_3O^+

32. Which of the following indicators is yellow at a pH of 10.0?

A. methyl red
B. phenol red
C. thymol blue
D. methyl violet

33. A sample containing 1.20×10^{-2} mol HCl is completely neutralized by 100.0 mL of $Sr(OH)_2$. What is the $\left[Sr(OH)_2\right]$?

A. 6.00×10^{-3} M
B. 6.00×10^{-2} M
C. 1.20×10^{-1} M
D. 2.4×10^{-1} M

34. Which of the following titrations will have the highest pH at the equivalence point?

A. HBr with NH_3

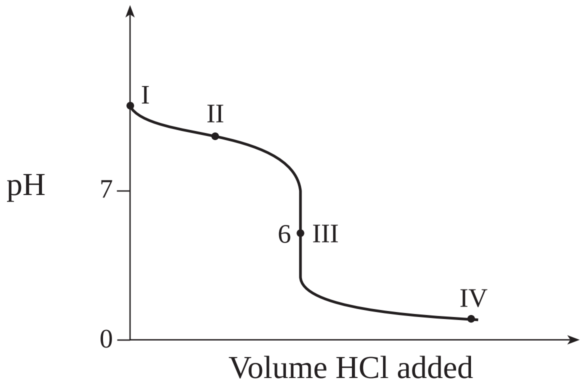
B. HNO_2 with KOH

C. HCl with Na_2CO_3

D. HNO_3 with NaOH

OVER

35. Consider the following graph for the titration of 0.1M NH_3 with 0.1M HCl:



A buffer solution is present at point

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

36. Which of the following solutions would require the greatest volume of 1.0M NaOH for complete neutralization?

A. 10.0mL of 1.0M HCl

B. 10.0mL of $2.0\text{M H}_2\text{SO}_4$

C. 10.0mL of $3.0\text{M H}_3\text{PO}_4$

D. 10.0mL of $4.0\text{M H}_2\text{C}_2\text{O}_4$

37. Which of the following is **not** a redox reaction?

A. $Cu + Br_2 \rightarrow CuBr_2$

B. $CO + H_2O \rightarrow CO_2 + H_2$

C. $CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$

D. $NaOH + HCl \rightarrow NaCl + H_2O$

38. The following reaction represents the process used to produce iron from iron(III) oxide:

$$Fe_2O_3 + 3CO \rightarrow 2Fe + 3CO_2$$

What is the reducing agent in this process?

A. Fe
B. CO
C. CO_2
D. Fe_2O_3

39. Consider the following reaction:

$$2HNO_2 + 2I^- + 2H^+ \rightarrow 2NO + I_2 + 2H_2O$$

The oxidation number for each nitrogen atom

A. increases by 1
B. increases by 2
C. decreases by 1
D. decreases by 2

40. Which of the following reactions is spontaneous?

A. $2I^- + Ag \rightarrow Ag^+ + I_2$
B. $Co^{2+} + Cu \rightarrow Co + Cu^{2+}$
C. $Cu^{2+} + Pb \rightarrow Pb^{2+} + Cu$
D. $Ni^{2+} + 2Ag \rightarrow 2Ag^+ + Ni$

41. Consider the following redox reaction for a lead-acid storage cell:

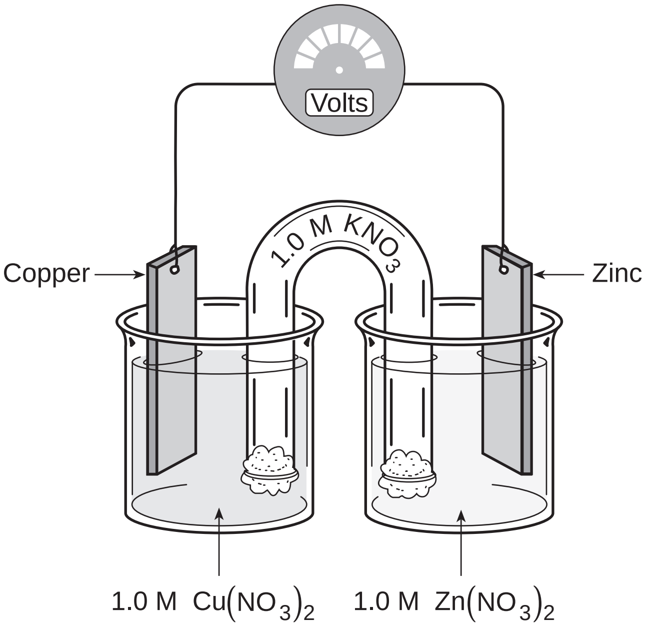
$$Pb + PbO_2 + 4H^+ + 2SO_4{}^{2-} \rightarrow 2PbSO_4 + 2H_2O$$

The balanced, reduction half-reaction is

A. $Pb + SO_4{}^{2-} \rightarrow PbSO_4 + 2e^-$
B. $Pb + 2H^+ + SO_4{}^{2-} \rightarrow PbSO_4 + H_2O + 2e^-$
C. $PbO_2 + 4H^+ + SO_4{}^{2-} + 2e^- \rightarrow PbSO_4 + 2H_2O$
D. $PbO_2 + SO_4{}^{2-} + 4H_2O + 2e^- \rightarrow PbSO_4 + 4OH^-$

OVER

Use the following diagram to answer questions 42 and 43.



42. Which of the following statements apply to this electrochemical cell?

I.	Electrons flow through the wire toward the copper electrode.
II.	The copper electrode increases in mass.
III.	Anions move toward the Zn half cell.

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

43. At equilibrium, the voltage of the cell above is

A. -1.10 V
B. 0.00 V
C. $+0.42$ V
D. $+1.10$ V

44. Consider the following reaction:

$$\mathrm{Cd^{2+}}_{(aq)} + \mathrm{Zn}_{(s)} \rightarrow \mathrm{Cd}_{(s)} + \mathrm{Zn^{2+}}_{(aq)}$$

The potential for the reaction is $+0.36\,\mathrm{V}$. What is the reduction potential for the cadmium ion?

A. -1.12 V
B. -0.40 V
C. $+0.40$ V
D. $+1.12$ V

45. Which of the following involves a nonspontaneous redox reaction?

A. fuel cell
B. electroplating
C. redox titration
D. carbon dry cell

46. Consider the following redox reaction:

$$2\mathrm{MnO_4}^- + 16\mathrm{H}^+ + 5\mathrm{Sn}^{2+} \rightarrow 2\mathrm{Mn}^{2+} + 8\mathrm{H_2O} + 5\mathrm{Sn}^{4+}$$

In a redox titration, 0.060 mol of $\mathrm{KMnO_4}$ reacts completely with a solution of $\mathrm{Sn(NO_3)_2}$. How many moles of $\mathrm{Sn(NO_3)_2}$ were present in the solution?

A. 0.024 mol
B. 0.060 mol
C. 0.15 mol
D. 0.30 mol

OVER

47. What substances are formed at the anode and cathode during electrolysis of molten sodium chloride, $NaCl_{(l)}$?

	ANODE	CATHODE
A.	O_2	H_2
B.	Na	Cl_2
C.	Cl_2	H_2
D.	Cl_2	Na

48. What is the minimum voltage required to form nickel from an aqueous solution of NiI_2 using inert electrodes?

A. 0.26 V
B. 0.28 V
C. 0.54 V
D. 0.80 V

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.

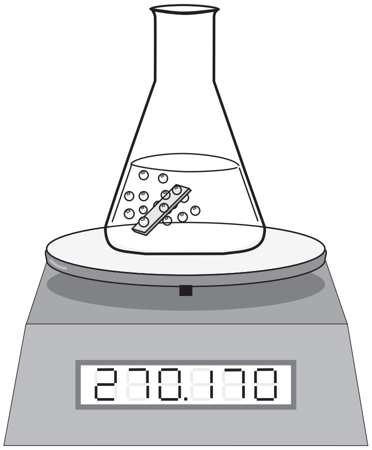
Your steps and assumptions leading to a solution must be written in the spaces below the questions.

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. An experiment is done to determine the rate of the following reaction:

$$2\mathrm{Al}_{(s)} + 6\mathrm{HCl}_{(aq)} \rightarrow 3\mathrm{H}_{2(g)} + 2\mathrm{AlCl}_{3(aq)}$$



The following data are collected:

TIME (s)	MASS OF FLASK PLUS CONTENTS (g)
0.0	270.230
30.0	270.200
60.0	270.170

Calculate the rate of consumption of Al in mol/min. **(3 marks)**

2. Consider the following equilibrium:

$$4HCl_{(g)} + O_{2(g)} \rightleftarrows 2H_2O_{(g)} + 2Cl_{2(g)} + \text{energy}$$

a) How does the **entropy** change in the forward direction? Explain your reasoning. **(1 mark)**

____

____

b) How does the **enthalpy** change in the forward direction? Explain your reasoning. **(1 mark)**

____

____

3. Consider the following equilibrium:

$$H_{2(g)} + I_{2(g)} \rightleftarrows 2HI_{(g)} \qquad K_{eq} = 1.2 \times 10^{-2}$$

A $2.0\,L$ flask is filled with $0.10\,mol$ HI. Calculate the concentration of H_2 at equilibrium.

(3 marks)

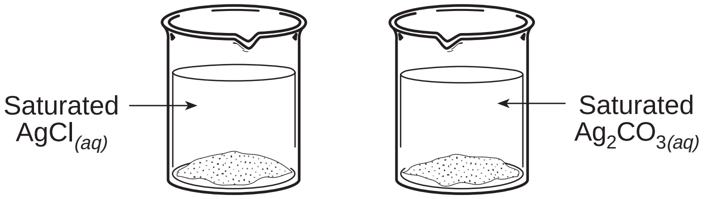
OVER

4. The solubility of $\mathrm{Mn}\left(\mathrm{IO}_3\right)_2$ is $4.8\times10^{-3}\ \mathrm{mol/L}$.

   a) Write the net ionic equation that describes a saturated solution of $\mathrm{Mn}\left(\mathrm{IO}_3\right)_2$. **(1 mark)**

   b) Calculate the concentrations of the ions in a saturated solution of $\mathrm{Mn}\left(\mathrm{IO}_3\right)_2$. **(1 mark)**

5. Consider the following saturated solutions at $25°\text{C}$:



Using calculations, identify the solution with the greater $\left[Ag^+\right]$. **(5 marks)**

OVER

6. Consider a Brönsted-Lowry acid-base equation, where HNO_2 is a reactant and $H_2PO_4^-$ is a product.

a) Complete the following equation. **(1 mark)**

$$HNO_2 + \_\_\_\_\_\_\_\_\_\_ \rightleftarrows \_\_\_\_\_\_\_\_\_\_ + H_2PO_4^-$$

b) Identify the weaker base in the equilibrium in part a). **(1 mark)**

7. A chemist prepares a solution by dissolving the salt $NaIO_3$ in water.

a) Write the equation for the dissociation reaction that occurs. **(1 mark)**

b) Write the equation for the hydrolysis reaction that occurs. **(1 mark)**

c) Calculate the value of the equilibrium constant for the hydrolysis in part b). **(1 mark)**

OVER

8. Calculate the pH of a solution prepared by adding 15.0 mL of 0.500 M H_2SO_4 to 35.0 mL of 0.750 M NaOH. **(4 marks)**

9. Balance the following redox reaction in basic solution. **(3 marks)**

$$MnO_4^{-} + C_2O_4^{2-} \rightarrow MnO_2 + CO_2 \qquad (\text{basic})$$

OVER

10. Describe **two** chemically different methods that can be used to prevent corrosion of iron and explain why each method works. **(2 marks)**

Method 1: ______________________________

____

Explanation: ______________________________

____

____

Method 2: ______________________________

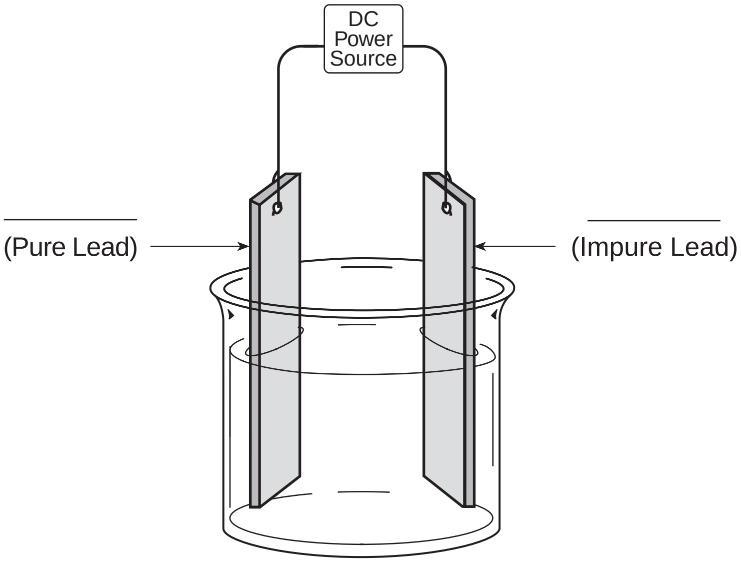
____

Explanation: ______________________________

____

____

11. Consider the following diagram for the electrorefining of lead:



a) On the diagram above, label the anode and the cathode. **(1 mark)**

b) Write the formula for a suitable electrolyte. **(1 mark)**

c) Write the equation for the reduction half-reaction. **(1 mark)**

END OF EXAMINATION

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INSERT STUDENT I.D. NUMBER (PEN)

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CHEMISTRY 12

August 1999

Course Code = CH

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CHEMISTRY 12

August 1999

Course Code = CH

Score for Question 1:

1. _____ (3)

Score for Question 2:

2. _____ (2)

Score for Question 3:

3. _____ (3)

Score for Question 4:

4. _____ (2)

Score for Question 5:

5. _____ (5)

Score for Question 6:

6. _____ (2)

Score for Question 7:

7. _____ (3)

Score for Question 8:

8. _____ (4)

Score for Question 9:

9. _____ (3)

Score for Question 10:

10. _____ (2)

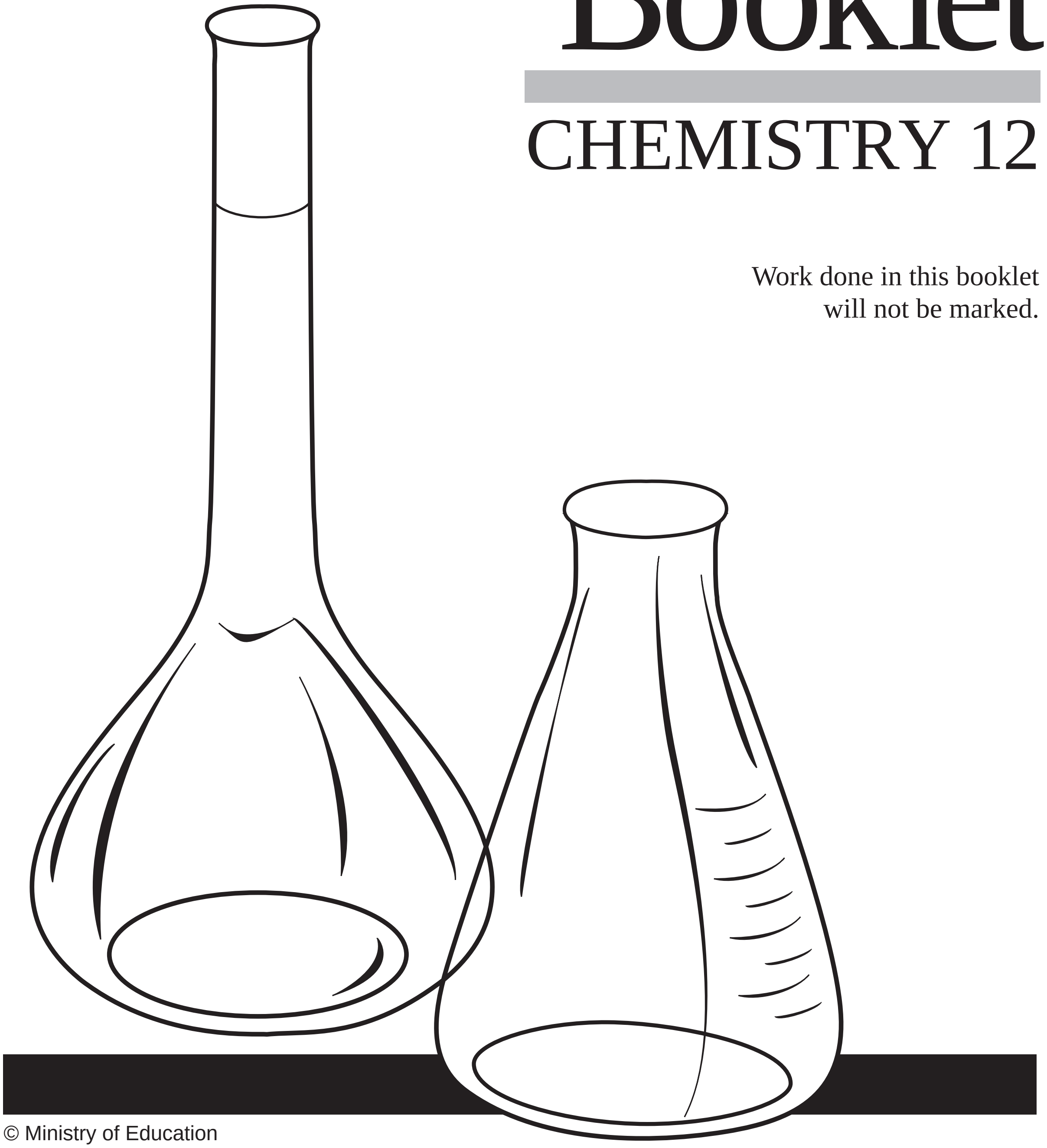
Score for Question 11:

11. _____ (3)

Data Booklet

CHEMISTRY 12

Work done in this booklet
will not be marked.



Revised November 1994

CONTENTS

REFERENCE

D.R. Lide, *CRC Handbook of Chemistry and Physics*, 74 edition, CRC Press, Boca Raton, 1993.

PERIODIC TABLE OF THE ELEMENTS

14 — Atomic number
Si — Symbol
Silicon — Name
28.1 — Atomic mass

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 Ha Hahnium (262)	106 Sg Seaborgium (263)	107 Uns Unnilseptium (262)	108 Uno Unniloctium (265)	109 Une Unnilennium (266)									

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.

58 Ce Cerium 140.1	59 Pr Praseodymium 140.9	60 Nd Neodymium 144.2	61 Pm Promethium (145)	62 Sm Samarium 150.4	63 Eu Europium 152.0	64 Gd Gadolinium 157.3	65 Tb Terbium 158.9	66 Dy Dysprosium 162.5	67 Ho Holmium 164.9	68 Er Erbium 167.3	69 Tm Thulium 168.9	70 Yb Ytterbium 173.0	71 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)

ATOMIC MASSES OF THE ELEMENTS

Based on mass of C^{12} at 12.00. Values in parentheses are the mass of the most stable or best known isotopes for elements which 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)
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
Hahnium	Ha	105	(262)
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

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

* Aqueous solutions are readily oxidized by air.

** Not stable in aqueous solutions.

Negative ions (anions)	
Bromide	Br^{-}
Carbonate	CO_3^{2-}
Chlorate	ClO_3^{-}
Chloride	Cl^{-}
Chlorite	ClO_2^{-}
Chromate	CrO_4^{2-}
Cyanide	CN^{-}
Dichromate	$Cr_2O_7^{2-}$
Dihydrogen phosphate	$H_2PO_4^{-}$
Ethanoate, Acetate	CH_3COO^{-}
Fluoride	F^{-}
Hydrogen carbonate, bicarbonate	HCO_3^{-}
Hydrogen oxalate, binoxalate	$HC_2O_4^{-}$
Hydrogen sulphate, bisulphate	HSO_4^{-}
Hydrogen sulphide, bisulphide	HS^{-}
Hydrogen sulphite, bisulphite	HSO_3^{-}
Hydroxide	OH^{-}
Hypochlorite	ClO^{-}
Iodide	I^{-}
Monohydrogen phosphate	HPO_4^{2-}
Nitrate	NO_3^{-}
Nitrite	NO_2^{-}
Oxalate	$C_2O_4^{2-}$
Oxide**	O^{2-}
Perchlorate	ClO_4^{-}
Permanganate	MnO_4^{-}
Phosphate	PO_4^{3-}
Sulphate	SO_4^{2-}
Sulphide	S^{2-}
Sulphite	SO_3^{2-}
Thiocyanate	SCN^{-}

SOLUBILITY OF COMMON COMPOUNDS IN WATER

The term soluble here means > $0.1 \ \text{mol/L}$ 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 BRÖNSTED-LOWRY ACIDS AND BASES

in aqueous solution at room temperature

Strength of Acid	Name of Acid	Acid		Base	K_a	Strength of Base
Strong ↑	Perchloric	$HClO_4$	$\rightarrow$	$H^+ + ClO_4^-$	very large	Weak ↓
	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	
Weak						Strong

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 1*M* in Water at 25˚ C

STRENGTH OF OXIDIZING AGENT	OXIDIZING AGENTS		REDUCING AGENTS	E˚(VOLTS)	STRENGTH OF REDUCING AGENT
strong	$F_{2(g)} + 2e^-$	⇄	$2F^-$	+2.87	weak
	$S_2O_8^{2-} + 2e^-$	⇄	$2SO_4^{2-}$	+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	
	$BrO_3^- + 6H^+ + 5e^-$	⇄	$\frac{1}{2}Br_{2(l)} + 3H_2O$	+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	Overpotential Effect
	$IO_3^- + 6H^+ + 5e^-$	⇄	$\frac{1}{2}I_{2(s)} + 3H_2O$	+1.20	
	$Br_{2(l)} + 2e^-$	⇄	$2Br^-$	+1.09	
	$AuCl_4^- + 3e^-$	⇄	$Au_{(s)} + 4Cl^-$	+1.00	
	$NO_3^- + 4H^+ + 3e^-$	⇄	$NO_{(g)} + 2H_2O$	+0.96	
	$Hg^{2+} + 2e^-$	⇄	$Hg_{(l)}$	+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	
	$\frac{1}{2}Hg_2^{2+} + e^-$	⇄	$Hg_{(l)}$	+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	
Overpotential Effect	$Ag_2S_{(s)} + 2e^-$	⇄	$2Ag_{(s)} + S^{2-}$	−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	
weak	$Li^+ + e^-$	⇄	$Li_{(s)}$	−3.04	strong