INSERT STUDENT I.D. NUMBER (PEN)

STICKER IN THIS SPACE

JUNE 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. Which of the following can be used to represent the rate of a reaction?

   A. $\frac{g}{L}$

   B. $\frac{g}{mol}$

   C. $\frac{g \bullet min}{mol}$

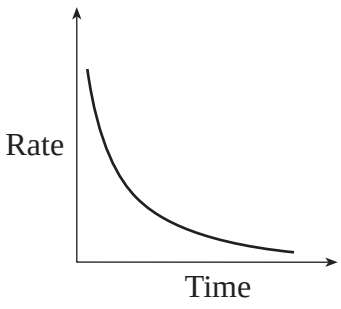
   D. $\frac{mol}{L \bullet min}$

2. Consider the following reaction:

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

   Which graph shows the relationship between rate of consumption of H_2O_2 and time?

   A.



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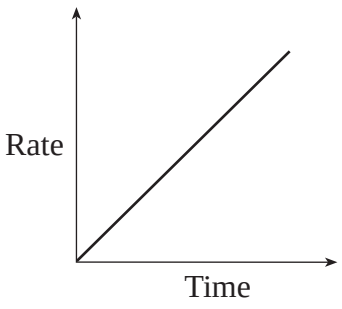

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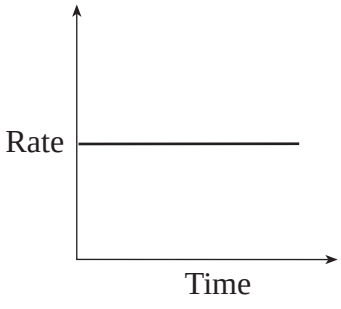

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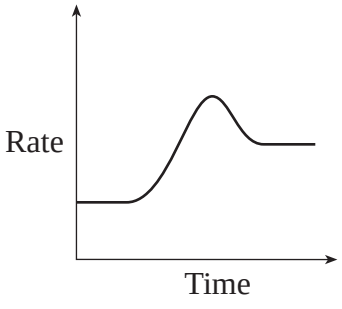


OVER

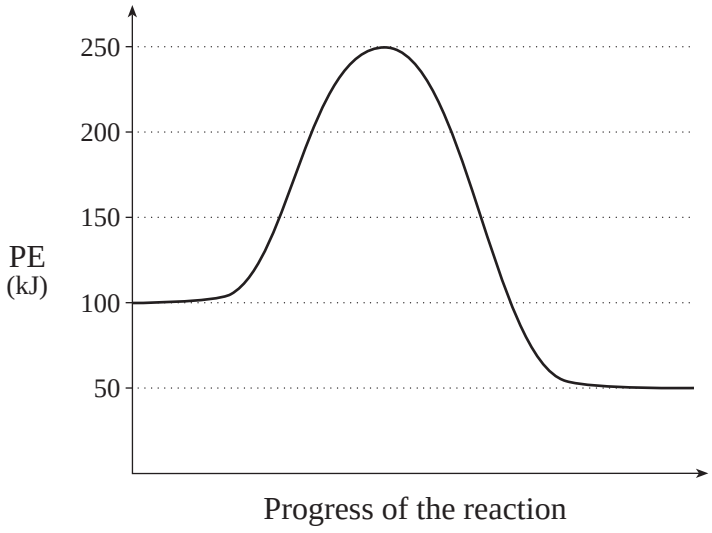
3. Consider the following reaction:

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

The rate of this reaction increases when more magnesium is added. This change is caused by the

A. addition of a catalyst.
B. increase in surface area.
C. change in nature of the reactants.
D. increase in concentration of reactants.

4. Consider the following PE diagram:

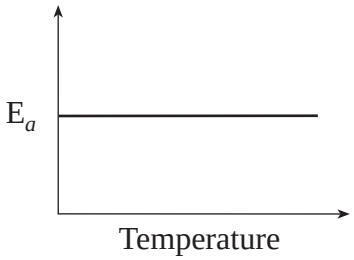


Which of the following describes the forward reaction?

	ΔH (kJ)	Activation Energy (kJ)
A.	+50	250
B.	–50	200
C.	–50	150
D.	+50	150

5. Which graph shows the relationship between activation energy $\left(E_a\right)$ and temperature?

A.



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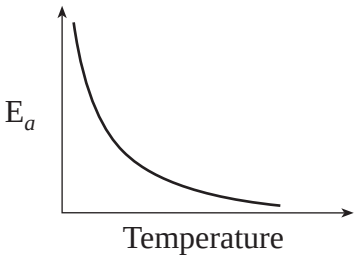

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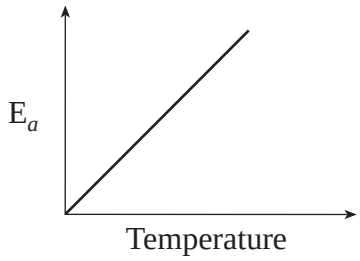

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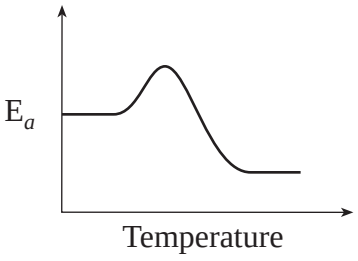


6. A catalyst changes the rate of a reaction by

   A. changing ΔH.
   B. increasing the temperature.
   C. decreasing the energy of the products.
   D. providing an alternate reaction mechanism.

7. Consider the following reaction:

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

Which of the following describes the changes in enthalpy and entropy as the reaction proceeds?

	ENTHALPY	ENTROPY
A.	increases	decreases
B.	increases	increases
C.	decreases	decreases
D.	decreases	increases

OVER

8. Consider the following equilibrium:

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

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

A. adding a catalyst
B. adding some SO_2
C. increasing the volume
D. decreasing the temperature

9. Methanol, CH_3OH, can be produced by the following:

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

The conditions that are necessary to maximize the equilibrium yield of CH_3OH are

A. low temperature and low pressure.
B. high temperature and low pressure.
C. low temperature and high pressure.
D. high temperature and high pressure.

10. A catalyst is added to a system already at equilibrium. How are the forward and reverse reaction rates affected by the addition of the catalyst?

	FORWARD RATE	REVERSE RATE
A.	increases	increases
B.	increases	remains constant
C.	remains constant	decreases
D.	remains constant	remains constant

11. Consider the following reaction:

$$2H_{2(g)} + O_{2(g)} \rightleftarrows 2H_2O_{(l)}$$

What is the equilibrium constant expression for the reaction?

A. $K_{eq} = [H_2]^2[O_2]$

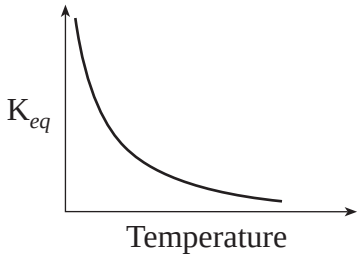
B. $K_{eq} = \dfrac{[H_2]^2[O_2]}{[H_2O]^2}$

C. $K_{eq} = \dfrac{[H_2O]^2}{[H_2]^2[O_2]}$

D. $K_{eq} = \dfrac{1}{[H_2]^2[O_2]}$

12. The relationship between K_{eq} and temperature for an exothermic reaction is represented by

A.



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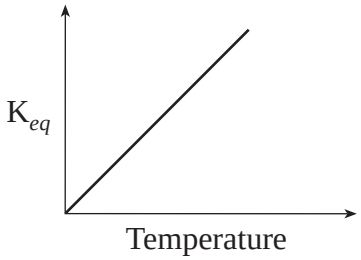

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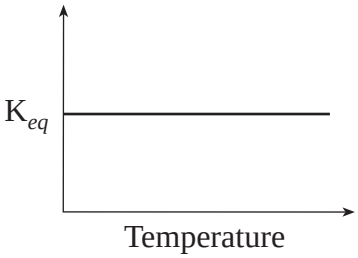

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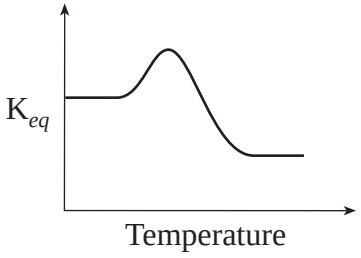


OVER

13. Consider the following equilibrium:

$$2\,NOBr_{(g)} \rightleftarrows 2\,NO_{(g)} + Br_{2(g)} \qquad K_{eq} = 6.4\times10^{-2}$$

At equilibrium, a $1.00\,L$ flask contains $0.030\,mol$ NOBr and $0.030\,mol$ NO. How many mol Br_2 are present?

A. 1.9×10^{-3} mol
B. 6.4×10^{-2} mol
C. 3.0×10^{-2} mol
D. 4.7×10^{-1} mol

14. The ion concentrations in $2.00\,L$ of $0.32\,M$ K_3PO_4 are

	$[K^+]$	$[PO_4^{3-}]$
A.	0.16 M	0.16 M
B.	0.32 M	0.32 M
C.	0.48 M	0.16 M
D.	0.96 M	0.32 M

15. Which of the following compounds is the least soluble in water?

A. CaS
B. $Fe(OH)_3$
C. $KMnO_4$
D. $NH_4HC_2O_4$

16. A solution contains two cations, each having a concentration of $0.20\,\text{M}$. When an equal volume of $0.20\,\text{M}$ OH^- is added, these cations are removed from the solution by precipitation. These ions are

A. Ba^{2+} and K^+
B. Sr^{2+} and Na^+
C. Mg^{2+} and Sr^{2+}
D. Mg^{2+} and Ca^{2+}

17. The solubility of $Mn(IO_3)_2$ is $4.8\times10^{-3}\,\text{M}$. What is the value of K_{sp} ?

A. 1.1×10^{-7}
B. 4.4×10^{-7}
C. 7.1×10^{-6}
D. 1.1×10^{-1}

18. The maximum $[SO_4^{2-}]$ that can exist in $1.0\times10^{-3}\,\text{M}$ $Ca(NO_3)_2$ without a precipitate forming is

A. 7.1×10^{-5} M
B. 1.0×10^{-3} M
C. 8.4×10^{-3} M
D. 7.1×10^{-2} M

19. A $1.0\times10^{-4}\,\text{M}$ solution has a pH of 10.00. The solute is a

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

OVER

20. Consider the following Brönsted-Lowry equilibrium system:

$$HSO_3^- + H_2PO_4^- \rightleftarrows SO_3^{2-} + H_3PO_4$$

What are the two Brönsted-Lowry bases in the equilibrium above?

A. HSO_3^- and SO_3^{2-}
B. $H_2PO_4^-$ and SO_3^{2-}
C. HSO_3^- and H_3PO_4
D. $H_2PO_4^-$ and H_3PO_4

21. The equation representing the predominant reaction of sodium ethanoate, $NaCH_3COO$, with water is

A. $CH_3COO^- + H_2O \rightleftarrows CH_3COOH + OH^-$
B. $CH_3COO^- + H_2O \rightleftarrows H_3O^+ + CH_2COO^{2-}$
C. $CH_3COOH + H_2O \rightleftarrows H_3O^+ + CH_3COO^-$
D. $CH_3COOH + H_2O \rightleftarrows CH_3COOH_2^+ + OH^-$

22. Which of the following solutions will have the lowest electrical conductivity?

A. 0.1M HF
B. 0.1M NaF
C. 0.1M H_2SO_3
D. 0.1M $NaHSO_3$

23. Which of the following is the strongest Brönsted-Lowry base?

A. NH_3
B. CO_3^{2-}
C. HSO_3^-
D. $H_2BO_3^-$

24. Consider the following:

	ION
I.	HCO_3^-
II.	$H_2PO_4^-$
III.	CH_3COO^-

The amphiprotic ions are

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

25. The ionization of water at room temperature is represented by

A. $H_2O \rightleftarrows 2H^+ + O^{2-}$

B. $2H_2O \rightleftarrows 2H_2 + O_2$

C. $2H_2O \rightleftarrows H_2 + 2OH^-$

D. $2H_2O \rightleftarrows H_3O^+ + OH^-$

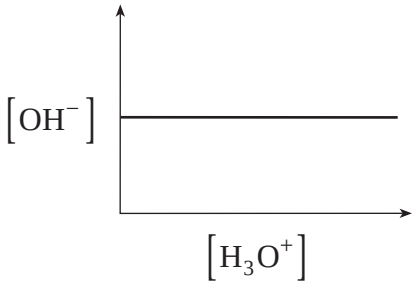
26. Addition of HCl to water causes

A. both $\left[H_3O^+\right]$ and $\left[OH^-\right]$ to increase.
B. both $\left[H_3O^+\right]$ and $\left[OH^-\right]$ to decrease.
C. $\left[H_3O^+\right]$ to increase and $\left[OH^-\right]$ to decrease.
D. $\left[H_3O^+\right]$ to decrease and $\left[OH^-\right]$ to increase.

OVER

27. Which of the following graphs describes the relationship between $[H_3O^+]$ and $[OH^-]$ in aqueous solutions at a constant temperature?

A.



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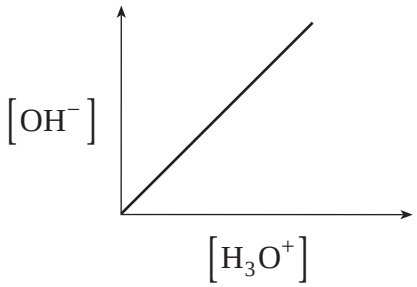

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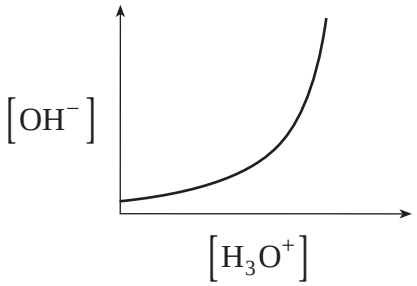

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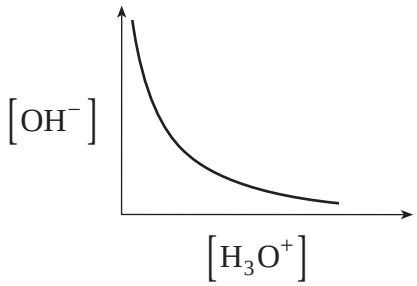


28. Consider the following:

I.	H_2SO_4
II.	HSO_4^-
III.	SO_4^{2-}

Which of the above is/are present in a reagent bottle labelled $1.0\,M\ H_2SO_4$?

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

29. The pH of a $0.10\,M$ KOH solution is

A. 0.10
B. 1.00
C. 13.00
D. 14.10

30. The equilibrium expression for the predominant reaction between the hydrogen oxalate ion, $HC_2O_4^-$, and water is

A. $K_a = \dfrac{\left[C_2O_4^{2-}\right]\left[H_3O^+\right]}{\left[HC_2O_4^-\right]}$

B. $K_b = \dfrac{\left[HC_2O_4^-\right]}{\left[C_2O_4^{2-}\right]\left[OH^-\right]}$

C. $K_a = \dfrac{\left[HC_2O_4^-\right]\left[H_3O^+\right]}{\left[C_2O_4^{2-}\right]}$

D. $K_b = \dfrac{\left[H_2C_2O_4\right]\left[OH^-\right]}{\left[HC_2O_4^-\right]}$

31. Which of the following salts will dissolve in water to produce a neutral solution?

A. LiF

B. $CrCl_3$

C. KNO_3

D. NH_4Cl

32. An indicator changes colour in the pH range 9.0 to 11.0. What is the value of K_a for the indicator?

A. 1×10^{-13}

B. 1×10^{-10}

C. 1×10^{-7}

D. 1×10^{1}

OVER

33. Which of the following always applies at the transition point for the indicator HInd?

A. $\left[\text{Ind}^-\right] = \left[\text{OH}^-\right]$

B. $\left[\text{HInd}\right] = \left[\text{Ind}^-\right]$

C. $\left[\text{Ind}^-\right] = \left[\text{H}_3\text{O}^+\right]$

D. $\left[\text{HInd}\right] = \left[\text{H}_3\text{O}^+\right]$

34. Calculate the $\left[\text{H}_3\text{O}^+\right]$ of a solution prepared by adding 10.0 mL of $2.0\,\text{M}$ HCl to 10.0 mL of $1.0\,\text{M}$ NaOH.

A. 0.020 M
B. 0.50 M
C. 1.0 M
D. 2.0 M

35. Consider the following:

I.	H_3O^+
II.	CH_3COO^-
III.	CH_3COOH

The purpose of a buffer system consisting of CH_3COOH and CH_3COONa is to maintain a relatively constant concentration of

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

36. Which of the following, when dissolved in water, will produce an acidic solution?

A. SrO

B. NO_2

C. CaO

D. Na_2O

37. Which of the following is capable of acting both as an oxidizing agent and a reducing agent?

A. H^+

B. Na^+

C. Sn^{2+}

D. MnO_4^-

38. Consider the following redox reaction:

$$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O$$

The substance undergoing reduction is

A. O_2

B. CO_2

C. H_2O

D. $C_6H_{12}O_6$

39. The oxidation number of P in $H_4P_2O_7$ is

A. −10

B. −5

C. +5

D. +10

OVER

40. A solution containing an unknown cation reacts spontaneously with both zinc and copper. The unknown cation is

A. $1.0\,M\ H^+$
B. $1.0\,M\ Ag^+$
C. $1.0\,M\ Sr^{2+}$
D. $1.0\,M\ Mn^{2+}$

41. Which of the following half-reactions is balanced?

A. $ClO^- + H_2O + e^- \rightarrow Cl_2 + 2OH^-$
B. $2ClO^- + H_2O + 2e^- \rightarrow Cl_2 + 3OH^-$
C. $2ClO^- + 2H_2O + 2e^- \rightarrow Cl_2 + 4OH^-$
D. $2ClO^- + 2H_2O \rightarrow Cl_2 + 4OH^- + 2e^-$

42. Which of the following is a spontaneous redox reaction?

A. $Ag^+ + I^- \rightarrow AgI$
B. $Ag^+ + Fe^{2+} \rightarrow Ag + Fe^{3+}$
C. $3Ag^+ + Au \rightarrow 3Ag + Au^{3+}$
D. $2Ag^+ + Ni^{2+} \rightarrow 2Ag + Ni$

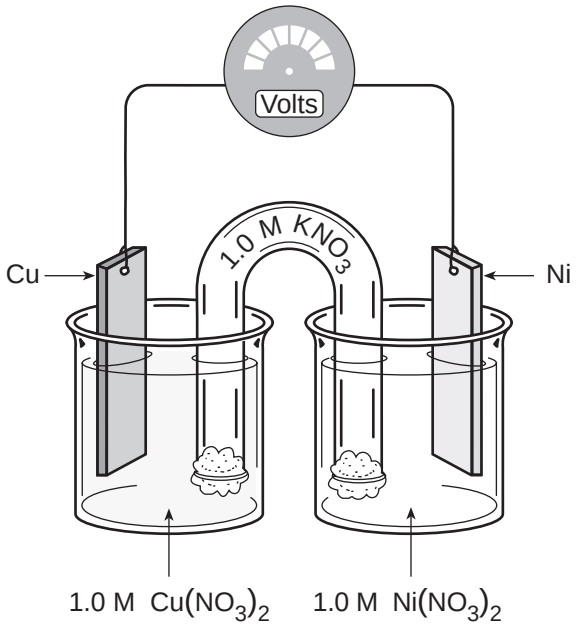
43. Salting of roads during the winter increases the corrosion of cars. This is because the salt

A. reacts with the iron.
B. provides an electrolyte.
C. acts as a reducing agent.
D. acts as an oxidizing agent.

44. Which of the following will **not** react spontaneously with $1.0\,M\ HCl$?

A. tin
B. lithium
C. mercury
D. aluminum

45. Consider the following electrochemical cell:



The half-reaction that occurs at the anode is

A. $Ni \rightarrow Ni^{2+} + 2e^-$

B. $Ni^{2+} + 2e^- \rightarrow Ni$

C. $Cu \rightarrow Cu^{2+} + 2e^-$

D. $Cu^{2+} + 2e^- \rightarrow Cu$

OVER

46. Which of the following can be produced by electrolysis from a $1.0\,M$ aqueous solution containing its ion?

A. nickel
B. sodium
C. aluminum
D. magnesium

47. In the electrolysis of molten $ZnCl_2$ using carbon electrodes, the reaction that occurs at the anode is

A. $Zn \rightarrow Zn^{2+} + 2e^-$

B. $Zn^{2+} + 2e^- \rightarrow Zn$

C. $2Cl^- \rightarrow Cl_2 + 2e^-$

D. $Cl_2 + 2e^- \rightarrow 2Cl^-$

48. In order for an electrolytic cell to operate, it must have

A. a voltmeter.
B. a salt bridge.
C. a power supply.
D. an aqueous solution.

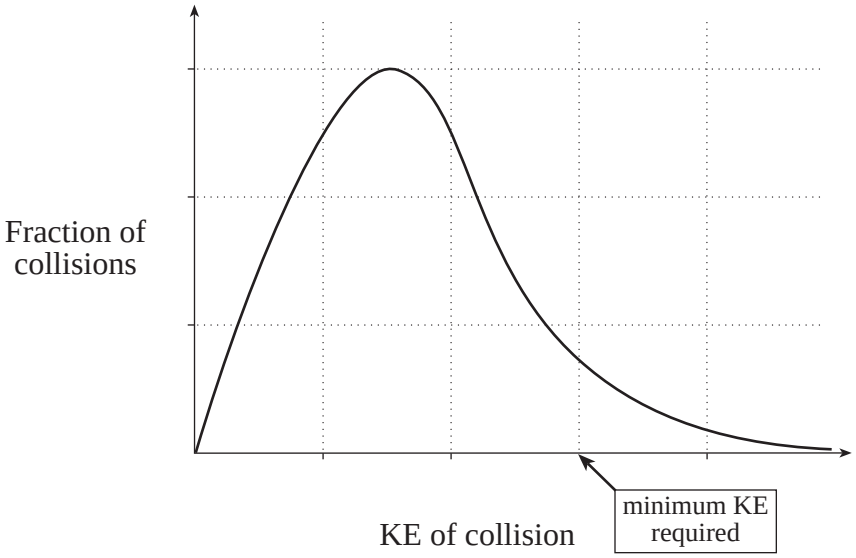
This is the end of the multiple-choice section.
Answer the remaining questions directly in this examination booklet.

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 KE distribution curve for colliding particles:



a) On the diagram above, sketch a line for the distribution of collisions at a higher temperature. **(2 marks)**

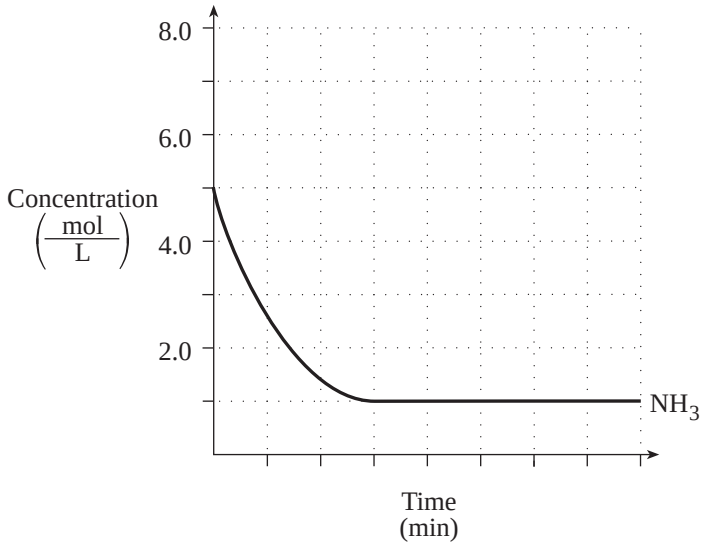
b) Shade in the area representing the collisions that could result in forming an activated complex at the lower temperature. **(1 mark)**

OVER

2. Consider the following equilibrium system:

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

A 1.00 L container is filled with 5.0 mol NH_3 and the system proceeds to equilibrium as indicated by the graph.



a) Draw and label the graph for N_2 and H_2. **(2 marks)**

b) Calculate the K_{eq} for $N_{2(g)} + 3H_{2(g)} \rightleftarrows 2NH_{3(g)}$. **(2 marks)**

3. State Le Chatelier's Principle. **(2 marks)**

4. Write the net ionic equation representing the reaction that occurs when $50.0\,\text{mL}$ of $0.20\,\text{M}$ $ZnSO_4$ and $50.0\,\text{mL}$ of $0.20\,\text{M}$ BaS are combined. **(2 marks)**

OVER

5. When $1.00\,g$ of $MgCO_3$ is added to $2.0\,L$ of water, some, but not all, will dissolve to form a saturated solution. Calculate the mass of solid that remains undissolved. **(4 marks)**

6. In aqueous solutions, H_3O^+ is the strongest acid present. This phenomenon is called the levelling effect. Explain why this occurs. **(2 marks)**

7. A $1.00\,\text{M}$ OCl^- solution has an $\left[OH^-\right]$ of $5.75\times10^{-4}\,\text{M}$.

a) Calculate K_b for OCl^-. **(3 marks)**

b) Calculate K_a for $HOCl$. **(1 mark)**

OVER

8. Calculate the mass of $NaOH$ needed to prepare $2.0\,L$ of a solution with a pH of 12.00.

(3 marks)

9. The data below were obtained in a redox titration of a $25.00\,\text{mL}$ sample containing Sn^{2+} ions using $0.125\,\text{M}$ $KMnO_4$ according to the following reaction:

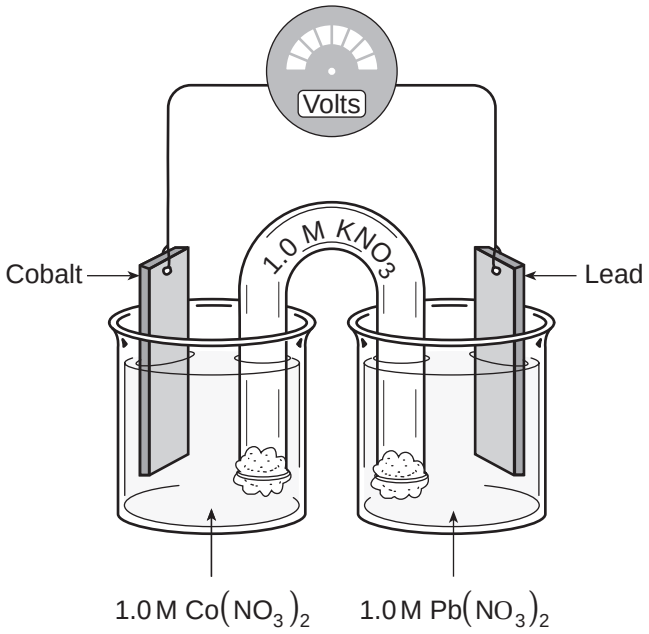
$$2MnO_4^- + 16H^+ + 5Sn^{2+} \rightarrow 2Mn^{2+} + 8H_2O + 5Sn^{4+}$$

	Volume of $KMnO_4$ used (mL)		
	Trial #1	Trial #2	Trial #3
Initial buret reading	2.00	13.80	24.55
Final buret reading	13.80	24.55	35.32

Calculate the $[Sn^{2+}]$ in the original sample. **(4 marks)**

OVER

10. Consider the following electrochemical cell:



a) Calculate the initial cell voltage. **(1 mark)**

b) What is the purpose of the salt bridge? **(1 mark)**

11. Consider the electrolysis of $1.0\,M\ H_2SO_4$ using inert platinum electrodes.

a) Write the oxidation half-reaction. **(1 mark)**

b) Write the reduction half-reaction. **(1 mark)**

END OF EXAMINATION

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CHEMISTRY 12

June 1999

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CHEMISTRY 12

June 1999

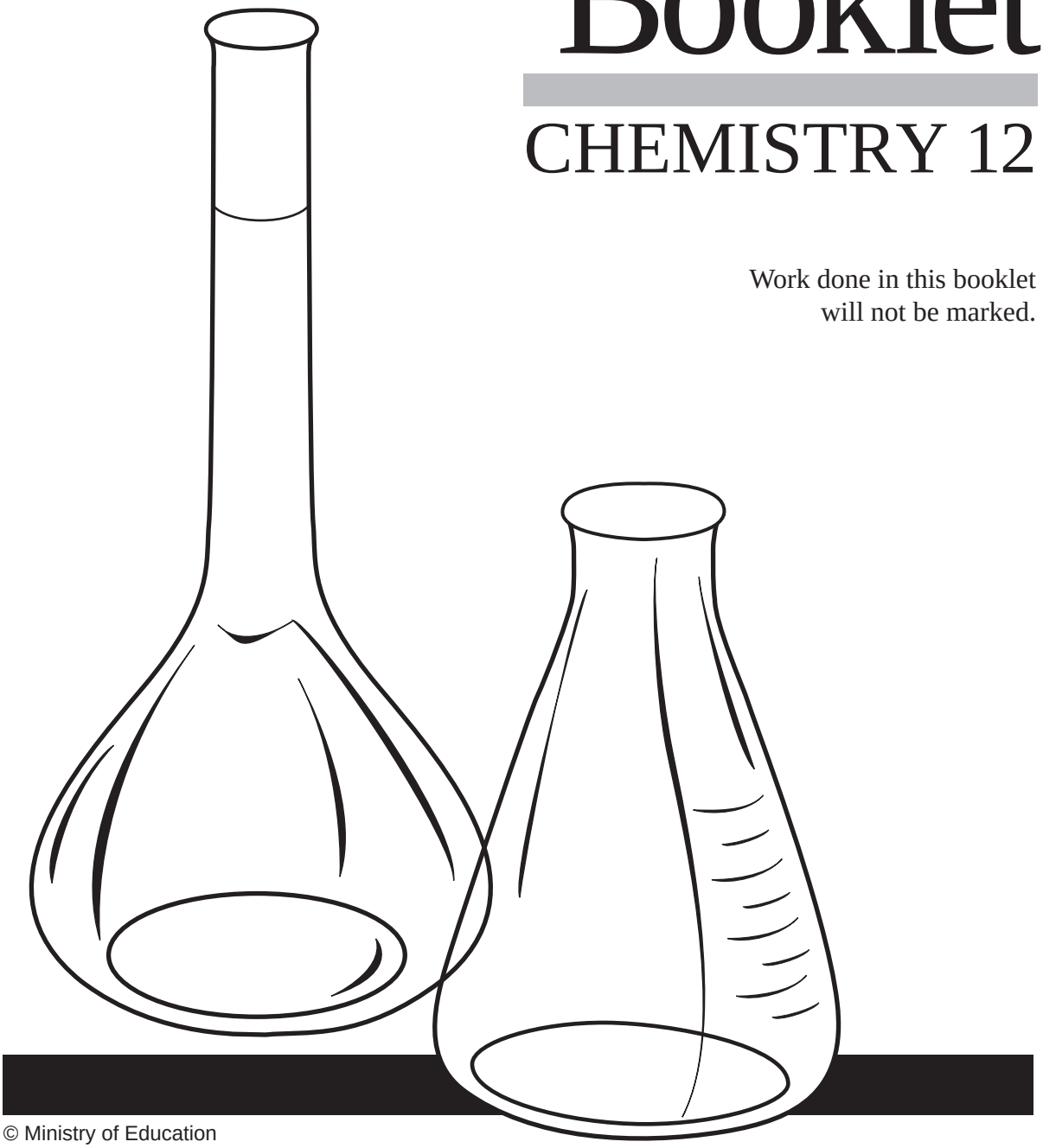
Course Code = CH

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

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

1												13	14	15	16	17	18
1 H Hydrogen 1.0	2																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	3	4	5	6	7	8	9	10	11	12	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)									

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

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)

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 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 mol/L at $25^{o}C$.

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	
	$IO_3^- + 6H^+ + 5e^-$	⇄	$\frac{1}{2}I_{2(s)} + 3H_2O$	+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	
	$Ag_2S_{(s)} + 2e^-$	⇄	$2Ag_{(s)} + S^{2-}$	−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

Overpotential Effect

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