MINISTRY USE ONLY

MINISTRY USE ONLY

Place Personal Education Number (PEN) here.

Place Personal Education Number (PEN) here.

MINISTRY USE ONLY

BRITISH COLUMBIA

Chemistry 12

JANUARY 2002

Course Code = CH

Student Instructions

1. Place the stickers with your Personal Education Number (PEN) in the allotted spaces above. **Under no circumstance is your name or identification, other than your Personal Education Number, to appear on this booklet.**
2. Ensure that in addition to this examination booklet, you have a **Data Booklet** and an **Examination Response Form**. Follow the directions on the front of the Response Form.
3. **Disqualification** from the examination will result if you bring books, paper, notes or unauthorized electronic devices into the examination room.
4. When instructed to open this booklet, **check the numbering of the pages** to ensure that they are numbered in sequence from page one to the last page, which is identified by

   END OF EXAMINATION.
5. At the end of the examination, place your Response Form inside the front cover of this booklet and return the booklet and your Response Form to the supervisor.

Question 1:

1. ☐ . ☐

(3)

Question 7:

7. ☐ . ☐

(4)

Question 2:

2. ☐ . ☐

(2)

Question 8:

8. ☐ . ☐

(5)

Question 3:

3. ☐ . ☐

(2)

Question 9:

9. ☐ . ☐

(4)

Question 4:

4. ☐ . ☐

(4)

Question 10:

10. ☐ . ☐

(1)

Question 5:

5. ☐ . ☐

(3)

Question 11:

11. ☐ . ☐

(4)

Question 6:

6. ☐ . ☐

(3)

Question 12:

12. ☐ . ☐

(5)

CHEMISTRY 12

JANUARY 2002

COURSE CODE = CH

GENERAL INSTRUCTIONS

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

2. All multiple-choice answers must be entered on the Response Form using an **HB pencil**. Multiple-choice answers entered in this examination booklet will **not** be marked.

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

4. Ensure that you use language and content appropriate to the purpose and audience of this examination. Failure to comply may result in your paper being awarded a zero.

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

CHEMISTRY 12 PROVINCIAL EXAMINATION

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

	Value	Suggested Time
PART A: 48 multiple-choice questions	60	70
PART B: 12 written-response questions	40	50
Total:	**100 marks**	**120 minutes**

2. The following tables can be found in the separate **Data Booklet**:
   - Periodic Table of the Elements
   - Atomic Masses of the Elements
   - Names, Formulae, and Charges of Some Common Ions
   - Solubility of Common Compounds in Water
   - Solubility Product Constants at 25°C
   - Relative Strengths of Brønsted-Lowry Acids and Bases
   - Acid-Base Indicators
   - Standard Reduction Potentials of Half-cells

   No other reference materials or tables are allowed.

3. **A calculator is essential for the Chemistry 12 Provincial Examination.** The calculator must be a hand-held device designed primarily for mathematical computations involving logarithmic and trigonometric functions and may also include graphing functions. Computers, calculators with a QWERTY keyboard, and electronic writing pads will not be allowed. Students must not bring any external devices to support calculators such as manuals, printed or electronic cards, printers, memory expansion chips or cards, or external keyboards. Students may have more than one calculator available during the examination. Calculators may not be shared and must not have the ability to either transmit or receive electronic signals. In addition to an approved calculator, students will be allowed to use rulers, compasses, and protractors during the examination.

THIS PAGE INTENTIONALLY BLANK

PART A: MULTIPLE CHOICE

Value: 60 marks **Suggested Time: 70 minutes**

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

Selected multiple-choice questions are worth 2 marks.

1. Which of the following has the greatest reaction rate? **(1 mark)**

   A. $C_{(s)} + O_{2(g)} \rightarrow CO_{2(g)}$
   B. $2H_2O_{2(\ell)} \rightarrow 2H_2O_{(\ell)} + O_{2(g)}$
   C. $2Al_{(s)} + 3CuCl_{2(aq)} \rightarrow 2AlCl_{3(aq)} + 3Cu_{(s)}$
   D. $NaCl_{(aq)} + AgNO_{3(aq)} \rightarrow AgCl_{(s)} + NaNO_{3(aq)}$

2. Which factor explains why potassium generally reacts faster than sodium? **(1 mark)**

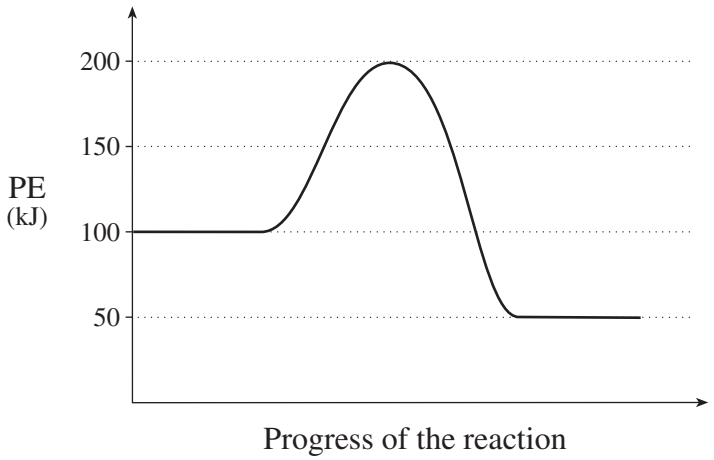
   A. surface area
   B. temperature
   C. concentration
   D. nature of reactants

3. What happens to the PE and KE of the reactant particles as the activated complex is formed? **(1 mark)**

	PE	KE
A.	increases	decreases
B.	increases	increases
C.	decreases	decreases
D.	decreases	increases

OVER

4. Consider the following PE diagram: **(2 marks)**



What are the values of ΔH and activation energy (E_a) for the forward reaction?

	ΔH (kJ)	E_a (kJ)
A.	−50	100
B.	−50	200
C.	+50	100
D.	+50	200

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

Step 1	$Cl_2 \rightarrow 2Cl$
Step 2	$CHCl_3 + Cl \rightarrow HCl + CCl_3$
Step 3	$CCl_3 + Cl \rightarrow CCl_4$

Which of the following is a reactant in the overall reaction?

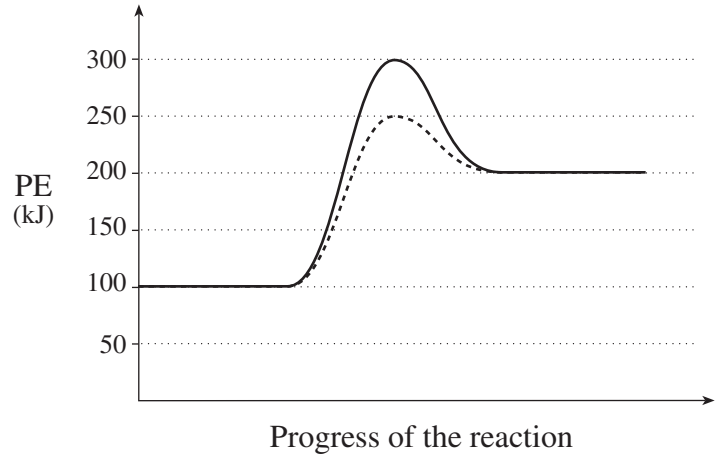
A. Cl

B. HCl

C. CCl_3

D. $CHCl_3$

6. Consider the following PE diagram for a catalyzed and uncatalyzed reaction: **(2 marks)**



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

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

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

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

Initially, SO_3 is added to an empty flask. How do the rate of the forward reaction and $[SO_3]$ change as the system proceeds to equilibrium?

	Forward Rate	$[SO_3]$
A.	decreases	increases
B.	decreases	decreases
C.	increases	increases
D.	increases	decreases

OVER

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

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

What positions do minimum enthalpy and maximum entropy tend toward?

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

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

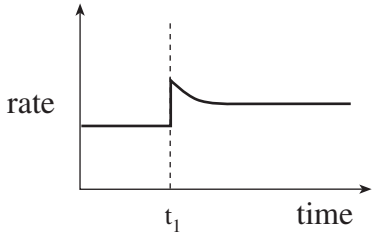
$$\mathbf{CO_{2(g)} + H_{2(g)} \rightleftarrows H_2O_{(g)} + CO_{(g)}}$$

9. Which two stresses will each cause the equilibrium to shift to the left? **(1 mark)**

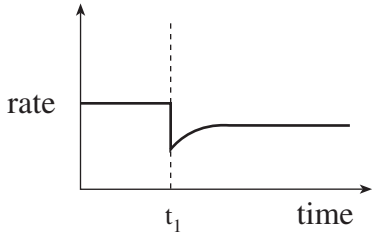
A. increase $[H_2]$, increase $[CO]$
B. decrease $[H_2]$, increase $[H_2O]$
C. increase $[CO_2]$, decrease $[CO]$
D. decrease $[CO_2]$, decrease $[H_2O]$

10. Which of the following graphs represents the forward rate of reaction when $H_2O_{(g)}$ is added to the above equilibrium at time = t_1 ? **(1 mark)**

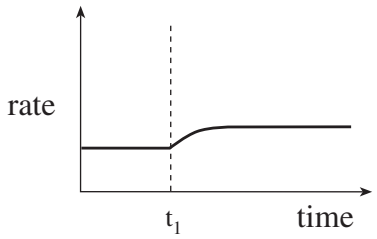
A.



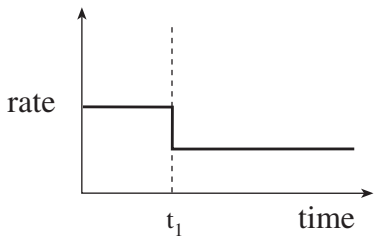
B.



C.



D.



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

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

Initially, some NH_3 is placed into a $1.0\,L$ container. At equilibrium there is $0.030\,mol$ N_2 present. What is the $[H_2]$ at this equilibrium?

A. $0.010\,mol/L$
B. $0.030\,mol/L$
C. $0.060\,mol/L$
D. $0.090\,mol/L$

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

$$K_{eq} = \frac{[NO_2]^4[H_2O]^6}{[NH_3]^4[O_2]^7}$$

A. $4NH_{3(g)} + 7O_{2(g)} \rightleftarrows 4NO_{2(g)} + 6H_2O_{(g)}$
B. $4NH_{3(aq)} + 7O_{2(g)} \rightleftarrows 4NO_{2(aq)} + 6H_2O_{(\ell)}$
C. $4NO_{2(aq)} + 6H_2O_{(\ell)} \rightleftarrows 4NH_{3(g)} + 7O_{2(g)}$
D. $4NO_{2(g)} + 6H_2O_{(g)} \rightleftarrows 4NH_{3(g)} + 7O_{2(g)}$

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

A. increasing [reactants]
B. decreasing [products]
C. increasing the temperature
D. decreasing the temperature

OVER

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

$$PCl_{5(g)} \rightleftarrows PCl_{3(g)} + Cl_{2(g)} \qquad K_{eq} = 9.0 \times 10^{-2}$$

In a 1.0 L container an equilibrium mixture contains 6.0×10^{-3} mol PCl_5 and 1.0×10^{-2} mol PCl_3 . How many moles of Cl_2 are also present at equilibrium?

A. 5.4×10^{-6} mol
B. 6.7×10^{-4} mol
C. 5.4×10^{-2} mol
D. 1.5×10^{-1} mol

15. The equation that describes the solubility equilibrium of $Ca_3(PO_4)_2$ is **(1 mark)**

A. $Ca_3(PO_4)_{2(s)} \rightleftarrows {Ca_3}^{6+}_{(aq)} + 2{PO_4}^{3-}_{(aq)}$
B. $Ca_3(PO_4)_{2(s)} \rightleftarrows 3Ca^{2+}_{(aq)} + 2{PO_4}^{3-}_{(aq)}$
C. $Ca_3(PO_4)_{2(s)} \rightleftarrows 2Ca^{3+}_{(aq)} + 3{PO_4}^{2-}_{(aq)}$
D. $Ca_3(PO_4)_{2(s)} \rightleftarrows \left(Ca^{2+}\right)_{3(aq)} + \left({PO_4}^{3-}\right)_{2(aq)}$

16. In a saturated solution of $Ag_2C_2O_4$, the $\left[Ag^+\right] = 2.2 \times 10^{-4}$ M .
What is the solubility of $Ag_2C_2O_4$ in this solution? **(1 mark)**

A. 4.3×10^{-11} M
B. 1.1×10^{-4} M
C. 2.2×10^{-4} M
D. 4.4×10^{-4} M

17. When equal volumes of $0.2\,\text{M}$ solutions are mixed, which of the following combinations forms a precipitate? **(1 mark)**

A. CaS and Sr(OH)_2

B. H_2SO_4 and MgCl_2

C. $(\text{NH}_4)_2\text{SO}_4$ and K_2CO_3

D. H_2SO_3 and NaCH_3COO

18. A solution contains $0.2\,\text{M}$ Zn^{2+} and $0.2\,\text{M}$ Sr^{2+}. An equal volume of a second solution was added, forming a precipitate with Sr^{2+} but not with Zn^{2+}. What is present in the second solution? **(1 mark)**

A $0.2\,\text{M}$ Cl^-

B. $0.2\,\text{M}$ OH^-

C. $0.2\,\text{M}$ SO_4^{2-}

D. $0.2\,\text{M}$ PO_4^{3-}

19. The K_{sp} expression for a saturated solution of $\text{Ba}_3(\text{AsO}_4)_2$ is **(1 mark)**

A. $\text{K}_{sp} = \left[\text{Ba}^{2+}\right]\left[\text{AsO}_4^{3-}\right]$

B. $\text{K}_{sp} = \left[\text{Ba}^{2+}\right]^3\left[\text{AsO}_4^{3-}\right]^2$

C. $\text{K}_{sp} = \left[3\text{Ba}^{2+}\right]\left[2\text{AsO}_4^{3-}\right]$

D. $\text{K}_{sp} = \left[3\text{Ba}^{2+}\right]^3\left[2\text{AsO}_4^{3-}\right]^2$

20. The solubility of NiCO_3 is $4.4 \times 10^{-2}\,\text{g/L}$. Determine the K_{sp} value of NiCO_3. **(2 marks)**

A. 1.4×10^{-7}

B. 3.7×10^{-4}

C. 1.9×10^{-3}

D. 2.1×10^{-1}

OVER

21. Calculate the solubility of $PbSO_4$. **(1 mark)**

A. 3.2×10^{-16} M
B. 1.8×10^{-8} M
C. 3.6×10^{-8} M
D. 1.3×10^{-4} M

22. When a solution containing Ag^+ is mixed with a solution containing BrO_3^- , the trial ion product is determined to be 2.5×10^{-7} . What would be observed? **(2 marks)**

A. A precipitate would form since trial ion product $< K_{sp}$.
B. A precipitate would form since trial ion product $> K_{sp}$.
C. A precipitate would not form since trial ion product $< K_{sp}$.
D. A precipitate would not form since trial ion product $> K_{sp}$.

23. Which of the following represents the complete neutralization of H_3PO_4 by NaOH? **(1 mark)**

A. $H_3PO_4 + NaOH \rightarrow NaH_2PO_4 + H_2O$
B. $H_3PO_4 + 3NaOH \rightarrow Na_3PO_4 + 3H_2O$
C. $H_3PO_4 + 2NaOH \rightarrow Na_2HPO_4 + 2H_2O$
D. $H_3PO_4 + NaOH \rightarrow NaH + HPO_4 + H_2O$

24. The conjugate base of HBO_3^{2-} is **(1 mark)**

A. BO_3^{2-}
B. BO_3^{3-}
C. HBO_3^-
D. $H_2BO_3^-$

25. When comparing equal volumes of $0.10\,M\ HNO_3$ with $0.10\,M\ HNO_2$, what would be observed? **(1 mark)**

A. The pH values would be the same.
B. The electrical conductivities would be different.
C. The effects on blue litmus paper would be different.
D. The volumes of $0.10\,M$ NaOH needed for neutralization would be different.

26. Consider the equilibrium: **(2 marks)**

$$HF_{(aq)} + HPO_4^{2-}{}_{(aq)} \rightleftarrows F^-_{(aq)} + H_2PO_4^-{}_{(aq)}$$

For the above equilibrium, identify the weaker acid and determine whether reactants or products are favoured.

	Weaker Acid	Side Favoured
A.	HF	products
B.	HF	reactants
C.	$H_2PO_4^-$	products
D.	$H_2PO_4^-$	reactants

27. The ionization of water can be represented by **(1 mark)**

A. $2H_2O_{(\ell)} \rightarrow 2H_{2(g)} + O_{2(g)}$
B. $H_2O_{(\ell)} \rightarrow 2H^+_{(aq)} + O^{2-}_{(aq)}$
C. $H_2O_{(\ell)} \rightarrow H_3O_{(aq)} + OH_{(aq)}$
D. $2H_2O_{(\ell)} \rightarrow H_3O^+_{(aq)} + OH^-_{(aq)}$

28. Calculate the pOH of a $0.050\,M$ HBr solution. **(1 mark)**

A. 0.30
B. 1.30
C. 12.70
D. 13.70

OVER

29. Calculate the value of K_b for HPO_4^{2-}. **(1 mark)**

A. 4.5×10^{-2}
B. 1.6×10^{-7}
C. 2.2×10^{-27}
D. 6.2×10^{-22}

30. Which of the following is the net ionic equation describing the hydrolysis of $KCN_{(aq)}$? **(1 mark)**

A. $K^+_{(aq)} + H_2O_{(\ell)} \rightleftarrows KOH_{(aq)} + H^+_{(aq)}$
B. $KCN_{(aq)} + H_2O_{(\ell)} \rightleftarrows K^+_{(aq)} + CN^-_{(aq)}$
C. $CN^-_{(aq)} + H_2O_{(\ell)} \rightleftarrows HCN_{(aq)} + OH^-_{(aq)}$
D. $CN^-_{(aq)} + H_2O_{(\ell)} \rightleftarrows 2H^+_{(aq)} + CNO^-_{(aq)}$

31. Which of the following 1.0 M salt solutions will be acidic? **(2 marks)**

A. $NaNO_3$
B. $NaHCO_3$
C. $NaHSO_4$
D. Na_2HPO_4

32. The pH at which an indicator changes colour is known as its **(1 mark)**

A. standard point.
B. transition point.
C. equivalence point.
D. stoichiometric point.

33. An indicator is blue at a pH of 12.0 and colourless at a pH of 1.0 .
Identify the indicator and determine its K_a value. **(2 marks)**

	Indicator	K_a
A.	thymolphthalein	1×10^{-10}
B.	thymolphthalein	3×10^{-7}
C.	bromthymol blue	2×10^{-7}
D.	bromthymol blue	3×10^{-7}

34. A 10.0 mL sample of H_2SO_3 is completely neutralized by titration with 18.6 mL of 0.10 M NaOH . Calculate the concentration of the acid. **(2 marks)**

A. 0.093 M
B. 0.19 M
C. 0.37 M
D. 0.74 M

35. A common source of NO_2 is **(1 mark)**

A. a fuel cell.
B. a lead smelter.
C. an aluminum smelter.
D. an automobile engine.

36. The pH at the stoichiometric point for the complete neutralization of a strong acid by a weak base will be **(1 mark)**

A. equal to 7.0
B. equal to 7.2
C. less than 7.0
D. greater than 7.2

OVER

37. A buffer solution can be prepared by dissolving equal moles of **(1 mark)**

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

38. A reducing agent **(2 marks)**

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

39. Which of the following could be produced by the reduction of NO_2 ? **(1 mark)**

A. NO
B. N_2O_4
C. N_2O_5
D. HNO_3

40. Consider the following redox equation: **(1 mark)**

$$3NO + SO_4^{2-} + Fe^{3+} + 2H_2O \rightarrow FeS + 3NO_3^{-} + 4H^{+}$$

Which of the following is being oxidized?

A. NO
B. Fe^{3+}
C. H_2O
D. SO_4^{2-}

41. What is the oxidation number of Cr in $Cr_2O_7^{2-}$? **(1 mark)**

A. +6
B. +7
C. +12
D. +14

42. Which of the following represents a spontaneous redox reaction? **(1 mark)**

A. $2Br^- + Hg^{2+} \rightarrow Br_2 + Hg$
B. $Cu + Sn^{4+} \rightarrow Cu^{2+} + Sn^{2+}$
C. $HCl + NaOH \rightarrow NaCl + H_2O$
D. $AuCl_4^- + 3Ag \rightarrow Au + 4Cl^- + 3Ag^+$

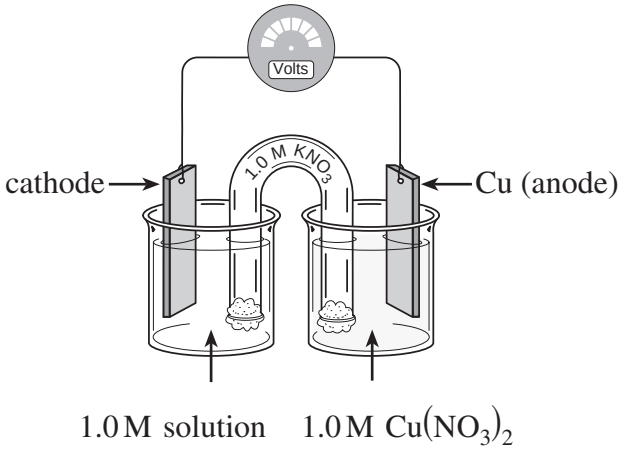
43. Which of the following is the balanced half-reaction for **(1 mark)**

$$N_2O \rightarrow NH_3OH^+ \qquad \text{(acidic)}$$

A. $N_2O + 4H^+ + 3e^- \rightarrow NH_3OH^+$
B. $N_2O + 3H^+ + H_2O \rightarrow NH_3OH^+ + 2e^-$
C. $N_2O + 6H^+ + H_2O \rightarrow 2NH_3OH^+ + 4e^-$
D. $N_2O + 6H^+ + H_2O + 4e^- \rightarrow 2NH_3OH^+$

OVER

Use the following diagram to answer questions 44 to 46.



44. Which material could be used as the cathode to produce an $E^{\circ}_{cell} = +0.46\,V$? **(1 mark)**

A. Pb
B. Co
C. Ag
D. MnO_2

45. In what directions do the electrons and cations move? **(2 marks)**

	Direction of Electrons	Direction of Cations
A.	toward the cathode	toward the anode
B.	toward the cathode	toward the cathode
C.	toward the anode	toward the anode
D.	toward the anode	toward the cathode

46. The concentration of Cu^{2+} in the copper half-cell will **(2 marks)**

A. increase as Cu loses electrons and is reduced.
B. increase as Cu loses electrons and is oxidized.
C. decrease as Cu gains electrons and is reduced.
D. decrease as Cu gains electrons and is oxidized.

47. Which of the following metals could be used to cathodically protect iron? **(1 mark)**

A. tin
B. lead
C. zinc
D. copper

48. Which of the following is formed at the anode during the electrolysis of 1.0 M KF ? **(1 mark)**

A. K
B. F_2
C. H_2
D. O_2

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

OVER

PART B: WRITTEN RESPONSE

Value: 40 marks **Suggested Time: 50 minutes**

INSTRUCTIONS:	You will be expected to communicate your knowledge and understanding of chemical principles in a clear and logical manner. Your steps and assumptions leading to a solution must be written in the spaces below the questions. Answers must include units where appropriate and be given to the correct number of significant figures. **For questions involving calculations, full marks will NOT be given for providing only an answer.**

1. Consider the following reaction: **(3 marks)**

$$C_{12}H_{22}O_{11(s)} \rightarrow 11\ H_2O_{(g)} + 12C_{(s)}$$

The rate of decomposition of $C_{12}H_{22}O_{11}$ is $0.75\,\text{mol/min}$.
What mass of C is produced in $10.0\,\text{seconds}$?

2. Define the term *activation energy*. **(2 marks)**

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

$$2NF_{2(g)} \rightleftarrows N_2F_{4(g)}$$

Equilibrium shifts to the right when volume is decreased. Describe the changes in reaction rates that cause this shift to the right.

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

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

Initially, $0.200\,\text{mol}\ H_2$ and $0.200\,\text{mol}\ I_2$ are added to an empty $2.00\,\text{L}$ container. At equilibrium, the $[I_2] = 0.020\,\text{mol/L}$. What is the value of K_{eq} ?

OVER

5. When equal volumes of $0.20\,\text{M}\ \text{Pb}(\text{NO}_3)_2$ and $0.20\,\text{M}\ \text{KCl}$ are mixed, a precipitate of PbCl_2 forms.

   a) Write the formula equation for the above reaction. **(1 mark)**

   b) Write the complete ionic equation for the above reaction. **(1 mark)**

   c) Write the net ionic equation for the above reaction. **(1 mark)**

6. Calculate the maximum $\left[\text{CO}_3^{2-}\right]$ that can exist in $0.0010\,\text{M}\ \text{Mg}(\text{NO}_3)_2$. **(3 marks)**

7. The two reactants in an acid-base reaction are $HNO_{2(aq)}$ and $HCO_3^-{}_{(aq)}$.

a) Write the equation for the above reaction. **(2 marks)**

b) Define the term *conjugate acid-base pair.* **(1 mark)**

_____

_____

c) Write the formulas for a conjugate acid-base pair for the above reaction. **(1 mark)**

OVER

8. At 10.0°C, $K_w = 2.95 \times 10^{-15}$ for pure water.

a) Calculate the pH of water at 10.0°C. **(3 marks)**

b) A mixture of the indicators phenolphthalein and bromcresol green is added to the water. What is the resulting colour of the mixture? Explain. **(2 marks)**

Resulting colour: _____

Explanation: _____

_____

9. At a particular temperature a $1.0\,M$ H_2S solution has a $pH = 3.75$. Calculate the value of K_a at this temperature. **(4 marks)**

10. What is the main function of a buffer solution? **(1 mark)**

_____

_____

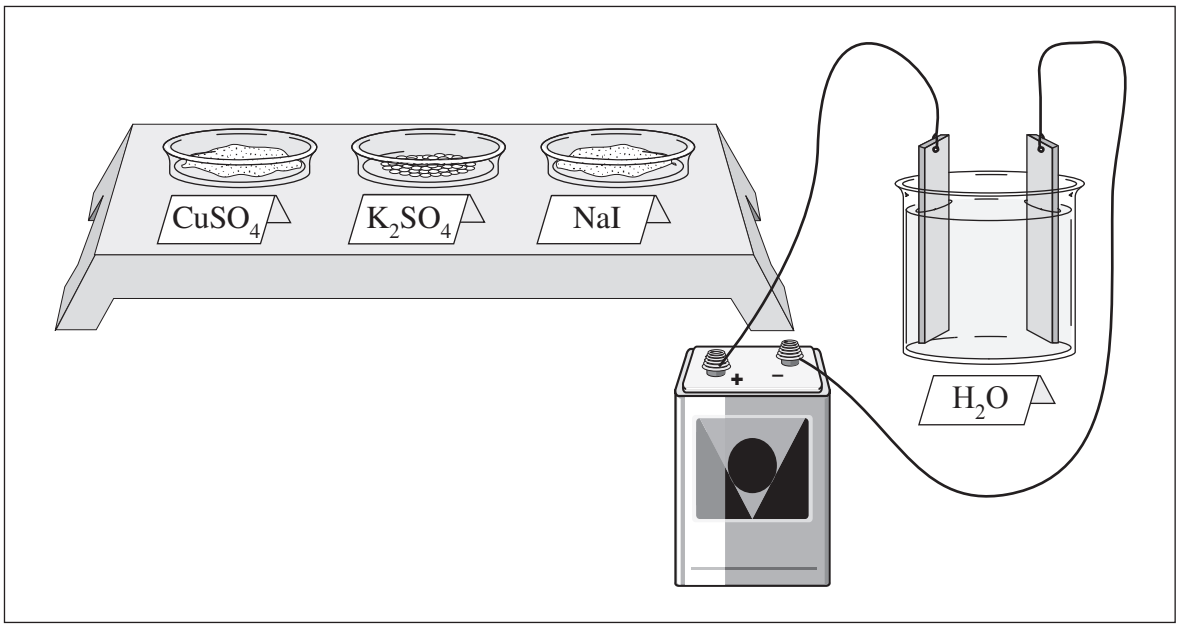
OVER

11. A titration is performed to determine the concentration of Fe^{2+} in 25.00 mL of an $FeSO_4$ solution. It requires 22.52 mL of 0.015 M $KMnO_4$ to reach the equivalence point according to the following equation:

$$MnO_4^- + 5Fe^{2+} + 8H^+ \rightarrow Mn^{2+} + 5Fe^{3+} + 4H_2O$$

Calculate the $\left[Fe^{2+}\right]$. **(4 marks)**

12. Consider the following diagram:



Students are asked to produce hydrogen and oxygen gas by the electrolysis of water. They are given three substances $(CuSO_4$, K_2SO_4 and NaI$)$ to choose from to prepare an electrolytic solution that will only produce hydrogen and oxygen.

a) Which substance should be selected? Explain why. **(3 marks)**

Substance: _____

Explanation: _____

_____

b) Write the equation for the half-reaction that occurs at the anode in the electrolytic cell. **(1 mark)**

c) Explain why it would **not** be acceptable to use a copper anode in this cell. **(1 mark)**

_____

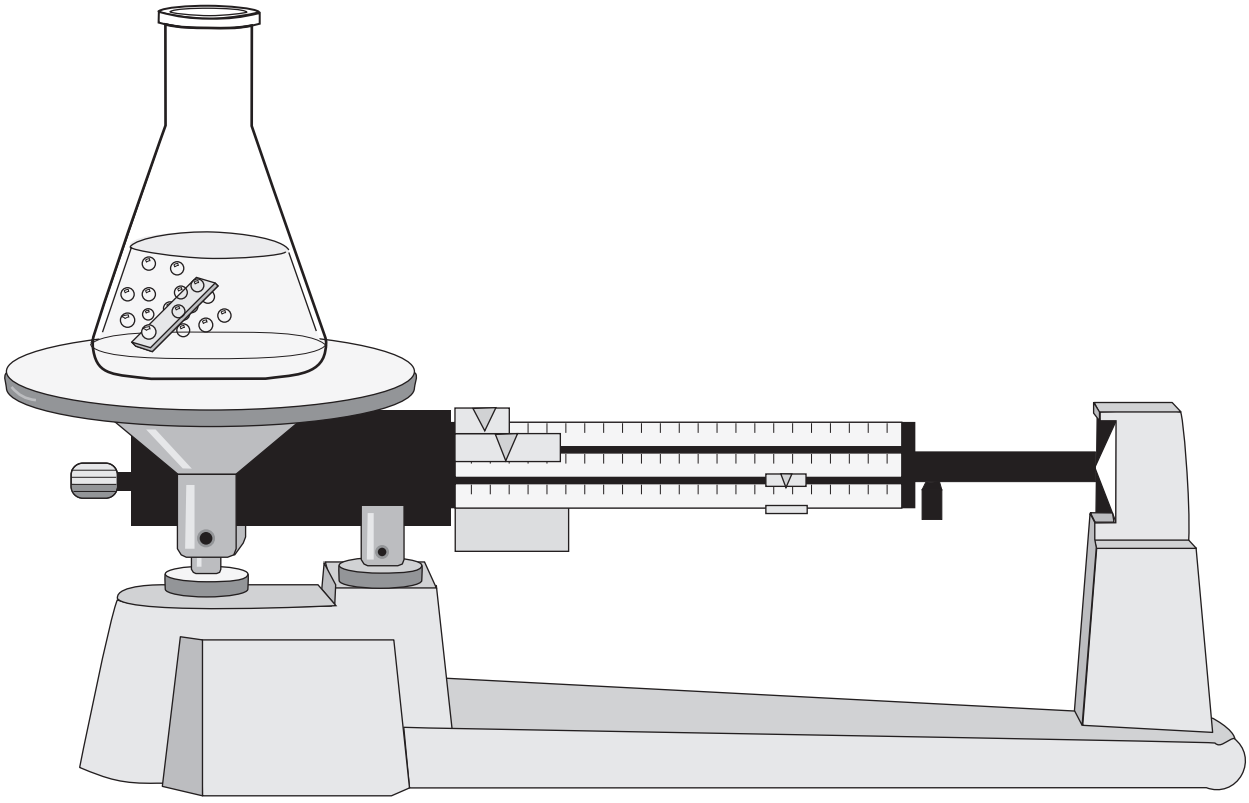
_____

END OF EXAMINATION

Data Booklet

CHEMISTRY 12

Work done in this booklet
will not be marked.



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 — Atomic Number
Si — Symbol
Silicon — Name
28.1 — 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