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BRITISH COLUMBIA

Chemistry 12

JUNE 2003

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. ☐ . ☐

(3)

Question 2:

2. ☐ . ☐

(2)

Question 8:

8. ☐ . ☐

(5)

Question 3:

3. ☐ . ☐

(3)

Question 9:

9. ☐ . ☐

(2)

Question 4:

4. ☐ . ☐

(3)

Question 10:

10. ☐ . ☐

(4)

Question 5:

5. ☐ . ☐

(5)

Question 11:

11. ☐ . ☐

(2)

Question 6:

6. ☐ . ☐

(5)

Question 12:

12. ☐ . ☐

(3)

Chemistry 12

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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. The calculator **must not** be programmable. Computers, calculators with a QWERTY keyboard or symbolic manipulation abilities, and electronic writing pads will not be allowed. Students must not bring any external devices (peripherals) to support calculators such as manuals, printed or electronic cards, printers, memory expansion chips or cards, CD-ROMS, libraries or external keyboards. Calculators may not be shared and must not have the ability to either transmit or receive electronic signals. In addition to an approved calculator, students will be allowed to use rulers, compasses, and protractors during the examination.

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PART A: MULTIPLE CHOICE

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

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

Note that some multiple-choice questions are worth 2 marks.

1. Which of the following reactions would have the greatest reaction rate at room temperature? **(1 mark)**

   A. $C_3H_{8(g)} + 5O_{2(g)} \rightarrow 3CO_{2(g)} + 4H_2O_{(g)}$

   B. $Ca_{(s)} + 2H_2O_{(\ell)} \rightarrow Ca(OH)_{2(aq)} + H_{2(g)}$

   C. $AgNO_{3(aq)} + NaCl_{(aq)} \rightarrow AgCl_{(s)} + NaNO_{3(aq)}$

   D. $Na_2CO_{3(s)} + 2HCl_{(aq)} \rightarrow 2NaCl_{(aq)} + H_2O_{(\ell)} + CO_{2(g)}$

2. Consider the following reaction:

$$2NO_{(g)} + O_{2(g)} \rightarrow 2NO_{2(g)} \qquad \Delta H = -114\ kJ$$

   How could the rate of this reaction be increased? **(1 mark)**

   A. Reduce the pressure.

   B. Increase the volume.

   C. Remove some $NO_{2(g)}$.

   D. Increase the temperature.

3. An activated complex can be described as **(1 mark)**

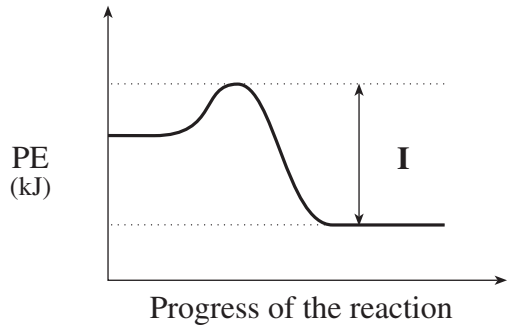
   A. a particle of maximum KE and minimum PE.
   B. a stable particle found in a reaction mechanism.
   C. an unstable particle that is neither reactant nor product.
   D. a particle which is first used then regenerated in a reaction mechanism.

OVER

4. Which of the following could result in an increase in reaction rate? **(1 mark)**

   A. an increase in the activation energy
   B. an increase in the reaction enthalpy
   C. an increase in the frequency of collisions
   D. an increase in the potential energy of the activated complex

5. Consider the following PE diagram:



   Which of the following describes the energy value indicated by **I**? **(1 mark)**

   A. heat of reaction
   B. activation energy for the reverse reaction
   C. activation energy for the forward reaction
   D. potential energy of the reaction intermediate

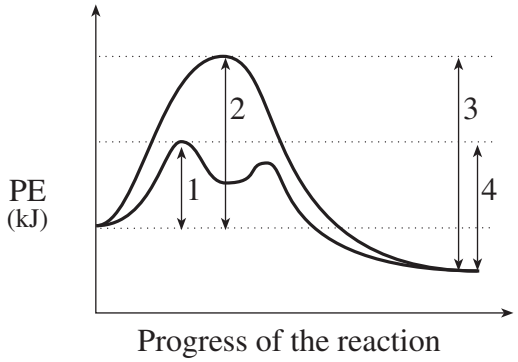
6. Consider the following reaction mechanism and overall reaction:

$$\begin{array}{rcrcrcl} \frac{1}{2}O_{2(g)} & + & NO_{(g)} & \rightarrow & NO_{2(g)} & & \\ & & NO_{2(g)} & \xrightarrow{\text{sunlight}} & NO_{(g)} & + & O_{(g)} \\ O_{(g)} & + & O_{2(g)} & \rightarrow & O_{3(g)} & & \\ \hline & & \frac{3}{2}O_{2(g)} & \rightarrow & O_{3(g)} & & \end{array}$$

   What is the catalyst in this mechanism? **(1 mark)**

   A. $O_{(g)}$
   B. $NO_{(g)}$
   C. $NO_{2(g)}$
   D. sunlight

7. Consider the following PE diagram:



Identify the activation energy for the forward uncatalysed reaction. **(1 mark)**

A. 1
B. 2
C. 3
D. 4

8. In which of the following will entropy and enthalpy factors favour the establishment of an equilibrium? **(1 mark)**

A. $CaCO_{3(s)} + 178\,kJ \overset{?}{\rightarrow} CaO_{(s)} + CO_{2(g)}$

B. $Mg_{(s)} + 2HCl_{(aq)} \overset{?}{\rightarrow} MgCl_{2(aq)} + H_{2(g)} + 425\,kJ$

C. $2C_{(s)} + 2H_{2(g)} \overset{?}{\rightarrow} C_2H_{4(g)} \qquad \Delta H = +52.3\,kJ$

D. $2C_2H_{6(g)} + 7O_{2(g)} \overset{?}{\rightarrow} 4CO_{2(g)} + 6H_2O_{(g)} \qquad \Delta H = -1560\,kJ$

9. Consider the following equilibrium:

$$CO_{(g)} + 2H_{2(g)} \rightleftarrows CH_3OH_{(g)} \qquad \Delta H = -91\,kJ$$

Which of the factors below would increase the concentration of CH_3OH at equilibrium? **(1 mark)**

A. an addition of CO
B. an increase in the volume
C. a decrease in the pressure
D. an increase in the temperature

OVER

10. Consider the following equilibrium:

$$PCl_{3(g)} + Cl_{2(g)} \rightleftarrows PCl_{5(g)}$$

If the volume of the system is decreased, how will the reaction rates in the new equilibrium compare with the rates in the original equilibrium? **(2 marks)**

	Forward Rate	Reverse Rate
A.	increases	increases
B.	increases	decreases
C.	decreases	decreases
D.	decreases	increases

11. Consider the following equilibrium:

$$\underset{\text{colourless}}{H_{2(g)}} + \underset{\text{purple}}{I_{2(g)}} \rightleftarrows \underset{\text{colourless}}{2HI_{(g)}} \qquad \Delta H = -71.9\,kJ$$

Which of the following would allow you to conclude that the system has reached equilibrium? **(1 mark)**

A. The pressure remains constant.
B. The reaction rates become zero.
C. The colour intensity remains constant.
D. The system shifts completely to the right.

12. Consider the following equilibrium:

$$Fe_2O_{3(s)} + 3CO_{(g)} \rightleftarrows 2Fe_{(s)} + 3CO_{2(g)}$$

Identify the equilibrium constant expression. **(1 mark)**

A. $K_{eq} = \dfrac{[CO_2]^3}{[CO]^3}$

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

C. $K_{eq} = \dfrac{[CO_2]^3[Fe]^2}{[Fe_2O_3][CO]^3}$

D. $K_{eq} = \dfrac{[Fe_2O_3][CO]^3}{[CO_2]^3[Fe]^2}$

13. Consider the following equilibrium system:

$$2NO_{(g)} + Cl_{2(g)} \rightleftarrows 2NOCl_{(g)} \qquad \Delta H = -77\,kJ$$

In which direction will the equilibrium shift and what happens to the value of K_{eq} when the temperature of the system is increased? **(1 mark)**

	Shift	K_{eq}
A.	right	increases
B.	right	decreases
C.	left	increases
D.	left	decreases

OVER

14. Consider the following equilibrium:

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

At equilibrium it was found that $[CO] = 0.105\,\text{mol/L}$, $[H_2] = 0.250\,\text{mol/L}$ and $[CH_3OH] = 0.00261\,\text{mol/L}$. Which of the following is the equilibrium constant value? **(1 mark)**

A. 9.94×10^{-2}
B. 0.398
C. 2.51
D. 10.0

15. What is the concentration of the ions in $3.0\,\text{L}$ of $0.50\ \text{M}\ Al_2(SO_4)_3$? **(2 marks)**

	$[Al^{3+}]$	$[SO_4{}^{2-}]$
A.	0.33 M	0.50 M
B.	1.0 M	1.5 M
C.	1.5 M	1.5 M
D.	3.0 M	4.5 M

16. Consider the following equilibrium:

$$MgCO_{3(s)} \rightleftarrows Mg^{2+}_{(aq)} + CO_3{}^{2-}_{(aq)}$$

Adding which of the following would cause the solid to dissolve? **(1 mark)**

A. HCl
B. K_2CO_3
C. $MgCO_3$
D. $Mg(NO_3)_2$

17. Which of the following compounds could be used to prepare a solution with a $\left[S^{2-}\right]$ greater than $0.1\,M$? **(1 mark)**

A. ZnS
B. PbS
C. Ag_2S
D. Rb_2S

18. Which of the following will **not** form a precipitate when mixed with an equal volume of $0.2\,M$ $AgNO_3$? **(2 marks)**

A. $0.2\,M$ NaBr
B. $0.2\,M$ $NaIO_3$
C. $0.2\,M$ $NaNO_3$
D. $0.2\,M$ $NaBrO_3$

19. A solution is prepared containing both $0.2\,M$ OH^- and $0.2\,M$ PO_4^{3-} ions. An equal volume of a second solution is added in order to precipitate only one of these two anions. The second solution must contain which of the following? **(1 mark)**

A. $0.2\,M$ Cs^+
B. $0.2\,M$ Zn^{2+}
C. $0.2\,M$ Pb^{2+}
D. $0.2\,M$ Sr^{2+}

20. Consider the following equilibrium:

$$CaS_{(s)} \rightleftarrows Ca^{2+}_{(aq)} + S^{2-}_{(aq)}$$

When $Ca(NO_3)_{2(aq)}$ is added to this solution, the equilibrium shifts to the **(1 mark)**

A. left and $\left[S^{2-}\right]$ increases.
B. left and $\left[S^{2-}\right]$ decreases.
C. right and $\left[S^{2-}\right]$ increases.
D. right and $\left[S^{2-}\right]$ decreases.

OVER

21. How many moles of Pb^{2+} are there in $500.0\,mL$ of a saturated solution of $PbSO_4$? **(1 mark)**

A. 3.2×10^{-16}
B. 9.0×10^{-9}
C. 6.7×10^{-5}
D. 1.3×10^{-4}

22. Which of the following compounds is least soluble in water? **(2 marks)**

A. CuI
B. BeS
C. CsOH
D. $AgBrO_3$

23. *A substance which produces hydroxide ions in solution* is a definition of which of the following? **(1 mark)**

A. an Arrhenius acid
B. an Arrhenius base
C. a Brønsted-Lowry acid
D. a Brønsted-Lowry base

24. Which of the following is generally true of acids, but **not** for bases? **(1 mark)**

A. $pH > 7$
B. release H^+ in solution
C. conduct current when in solution
D. cause indicators to change colour

25. Which of the following $1.0\,M$ solutions will have the highest electrical conductivity? **(1 mark)**

A. HI
B. HF
C. HCN
D. HNO_2

26. Consider the following equilibrium:

$$HOI + F^- \rightleftarrows OI^- + HF$$

Reactants are favoured in this equilibrium. Which of the following describes the relative strengths of the acids and the bases? **(2 marks)**

	Stronger Acid	Stronger Base
A.	HF	F^-
B.	HF	OI^-
C.	HOI	F^-
D.	HOI	OI^-

27. Which of the following is true for a neutral aqueous solution? **(1 mark)**

A. $\left[H_3O^+\right] = 0.0\,M$
B. $\left[H_3O^+\right] = \left[OH^-\right]$
C. $\left[H_3O^+\right] > \left[OH^-\right]$
D. $\left[H_3O^+\right] < \left[OH^-\right]$

OVER

28. Which of the following is a definition of pK_w ? **(1 mark)**

A. $pK_w = -\log K_w$

B. $pK_w = pH - pOH$

C. $pK_w = 7.0$ at 25°C

D. $pK_w = [H_3O^+][OH^-]$

29. Consider the following equilibrium:

$$H_2CO_{3(aq)} + H_2O_{(\ell)} \rightleftarrows H_3O^+_{(aq)} + HCO_3^-{}_{(aq)}$$

What is the equilibrium expression? **(1 mark)**

A. $K_a = \dfrac{[H_3O^+][HCO_3^-]}{[H_2CO_3]}$

B. $K_a = \dfrac{[H_2CO_3]}{[H_3O^+][HCO_3^-]}$

C. $K_a = \dfrac{[H_2CO_3][H_2O]}{[H_3O^+]\,[HCO_3^-]}$

D. $K_a = \dfrac{[H_3O^+][HCO_3^-]}{[H_2CO_3][H_2O]}$

30. Which of the following describes the net ionic equation for the hydrolysis of a $NaNO_2$ solution? **(1 mark)**

A. $NaNO_{2(s)} \rightleftarrows Na^+_{(aq)} + NO_2^-{}_{(aq)}$

B. $NO_2^-{}_{(aq)} + H_2O_{(\ell)} \rightleftarrows HNO_{2(aq)} + OH^-_{(aq)}$

C. $Na^+_{(aq)} + 2H_2O_{(\ell)} \rightleftarrows H_3O^+_{(aq)} + NaOH_{(aq)}$

D. $NaNO_{2(s)} + H_2O_{(\ell)} \rightleftarrows NaOH_{(aq)} + HNO_{2(aq)}$

31. The $HC_2O_4^-{}_{(aq)}$ ion will act as **(2 marks)**

A. a base since $K_a < K_b$
B. a base since $K_a > K_b$
C. an acid since $K_a < K_b$
D. an acid since $K_a > K_b$

32. What do a chemical indicator and a buffer solution typically both contain? **(1 mark)**

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

33. What is the approximate pH and K_a at the transition point for phenol red? **(2 marks)**

A. $pH = 6.6,\ K_a = 3 \times 10^{-7}$
B. $pH = 7.3,\ K_a = 1 \times 10^{-14}$
C. $pH = 7.3,\ K_a = 5 \times 10^{-8}$
D. $pH = 8.0,\ K_a = 1 \times 10^{-8}$

34. When performing a titration experiment, the indicator must always have **(1 mark)**

A. a distinct colour change at $pH = 7.0$.
B. the ability to change from colourless to pink.
C. a transition point that is close to the equivalence point.
D. an equivalence point that is close to the stoichiometric point.

OVER

35. A 25.0 mL sample of H_2SO_4 is titrated with 30.0 mL of 0.150 M NaOH. Calculate the concentration of the H_2SO_4 . **(2 marks)**

A. 0.0409 M
B. 0.0900 M
C. 0.125 M
D. 0.180 M

36. Consider the following buffer equilibrium:

$$H_2CO_{3(aq)} + H_2O_{(\ell)} \rightleftarrows H_3O^+_{(aq)} + HCO_3^-{}_{(aq)}$$

What happens when a small amount of $NaOH_{(aq)}$ is added? **(2 marks)**

A. $\left[H_3O^+\right]$ increases, then the equilibrium shifts to the left.
B. $\left[H_3O^+\right]$ decreases, then the equilibrium shifts to the left.
C. $\left[H_3O^+\right]$ increases, then the equilibrium shifts to the right.
D. $\left[H_3O^+\right]$ decreases, then the equilibrium shifts to the right.

37. What is a common source of $SO_{2(g)}$? **(1 mark)**

A. a fuel cell
B. a car battery
C. a lead smelter
D. corrosion of iron

38. Which of the following represents an oxidation? **(1 mark)**

A. $2H^+ + S \rightarrow H_2S$
B. $2SO_4^{2-} \rightarrow S_2O_8^{2-}$
C. $Na^+ + Cl^- \rightarrow NaCl$
D. $SO_2 + H_2O \rightarrow 2H^+ + SO_3^{2-}$

39. Identify the oxidation number for manganese in MnO_4^-. **(1 mark)**

A. -7
B. $+7$
C. $+8$
D. $+9$

40. Which of the following is more difficult to reduce than the $H^+_{(aq)}$ ion? **(1 mark)**

A. I_2
B. Ag^+
C. Zn^{2+}
D. Cu^{2+}

41. Nitric oxide (NO) can be prepared by the oxidation of Cu with NO_3^- in acidic solution. Copper is oxidized to Cu^{2+} and NO_3^- is reduced to NO. Which of the following equations correctly describes this process? **(1 mark)**

A. $Cu + NO_3^- + 4H^+ \rightarrow Cu^{2+} + NO + 2H_2O$
B. $Cu + NO_3^- + 2H^+ \rightarrow Cu^{2+} + NO_2 + H_2O$
C. $Cu + 4NO_3^- + 4H^+ \rightarrow Cu^{2+} + 2NO_2 + 2H_2O$
D. $3Cu + 2NO_3^- + 8H^+ \rightarrow 3Cu^{2+} + 2NO + 4H_2O$

42. Acidified potassium permanganate $(KMnO_4)$ solution is often used in redox titrations. Permanganate reacts with Sn^{2+} as follows:

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

A $10.0\,mL$ solution containing Sn^{2+} is titrated with $19.3\,mL$ of $0.10\,M$ $KMnO_4$. What is the $\left[Sn^{2+}\right]$ in the solution? **(2 marks)**

A. 0.077 M
B. 0.19 M
C. 0.25 M
D. 0.48 M

OVER

43. Given the following half-cell reactions:

$$PbO_2 + 4H^+ + SO_4^{2-} + 2e^- \rightleftarrows PbSO_4 + 2H_2O \qquad E° = +1.69\,V$$

$$PbSO_4 + 2e^- \rightleftarrows Pb + SO_4^{2-} \qquad E° = -0.36\,V$$

Which of the following best describes the overall reaction and the standard cell voltage in a lead acid storage battery? **(1 mark)**

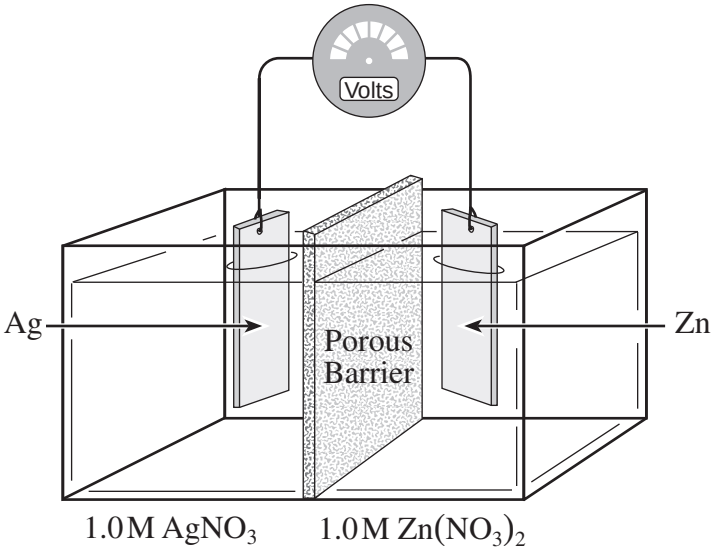
A. $Pb + 2H_2O \rightarrow PbO_2 + 4H^+ + 4e^-$ $\quad E°_{cell} = +1.33$

B. $PbO_2 + 4H^+ + 4e^- \rightarrow Pb + 2H_2O$ $\quad E°_{cell} = +1.33$

C. $Pb + PbO_2 + 2SO_4^{2-} + 4H^+ \rightarrow 2PbSO_4 + 2H_2O$ $\quad E°_{cell} = +2.05$

D. $2PbSO_4 + 2H_2O \rightarrow Pb + PbO_2 + 2SO_4^{2-} + 4H^+$ $\quad E°_{cell} = +2.05$

44. Consider the following electrochemical cell:



What is the anode half-reaction? **(1 mark)**

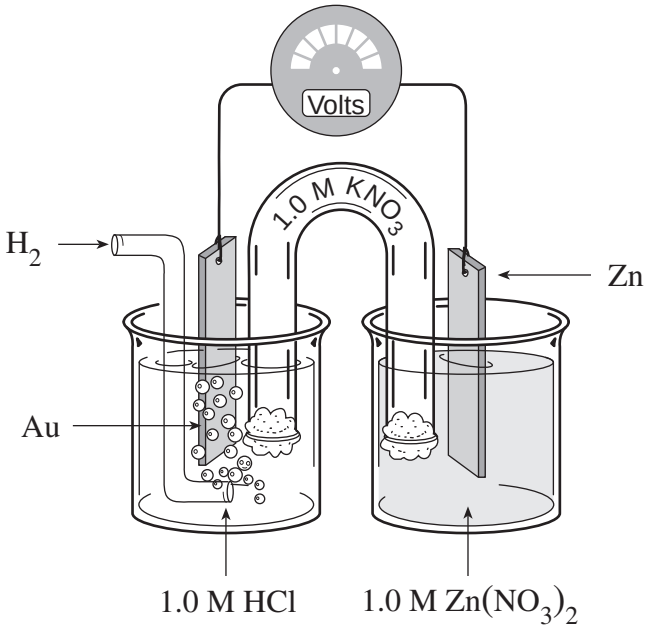
A. $Ag \rightarrow Ag^+ + e^-$

B. $Ag^+ + e^- \rightarrow Ag$

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

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

45. Consider the following cell:



What is the value of the standard cell potential? **(2 marks)**

A. −0.76 V
B. +0.76 V
C. +2.12 V
D. +2.26 V

46. Two separate reactions involved in the refining of copper ore are:

Reaction I	$2Cu_2S + 3O_2 \rightarrow 2Cu_2O + 2SO_2$
Reaction II	$Cu_2S + 2Cu_2O \rightarrow 6Cu + SO_2$

What happens to the copper ions during this process? **(1 mark)**

A. They are reduced in Reaction I.
B. They are reduced in Reaction II.
C. They are oxidized in Reaction I.
D. They are oxidized in Reaction II.

OVER

47. Why is aluminum a good choice for the manufacture of outdoor structures? **(1 mark)**

A. Pure aluminum is easily reduced.
B. Pure aluminum is not easily oxidized.
C. Pure aluminum is easily reduced, but forms a protective coating.
D. Pure aluminum is easily oxidized, but forms a protective coating.

48. Which of the following are produced at the anode and the cathode during the electrolysis of aqueous calcium iodide using carbon electrodes? **(2 marks)**

	Anode	Cathode
A.	Iodine	Calcium
B.	Hydrogen	Oxygen
C.	Oxygen	Hydrogen
D.	Iodine	Hydrogen

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

PART B: WRITTEN RESPONSE

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

INSTRUCTIONS:	You are 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 in an open flask: **(3 marks)**

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

A 155.0 g sample of $CaCO_{3(s)}$ is placed in the flask and $HCl_{(aq)}$ is added.
The reaction consumes $HCl_{(aq)}$ at an average rate of 0.200 mol/min for 10.0 min.
What mass of $CaCO_{3(s)}$ remains?

OVER

2. a) Write the equation for Step 3 in the following reaction mechanism. **(1 mark)**

Step 1	$2NO \rightarrow N_2O_2$
Step 2	$N_2O_2 + H_2 \rightarrow N_2O + H_2O$
Step 3	**?**
Overall Reaction	$2NO + 2H_2 \rightarrow N_2 + 2H_2O$

Step 3: _____

b) Identify a reaction intermediate in the above mechanism. **(1 mark)**

3. Consider the following exothermic reaction:

$$C_3H_{8(g)} + 5O_{2(g)} \xrightarrow{?} 3CO_{2(g)} + 4H_2O_{(g)}$$

Explain, in terms of increasing or decreasing entropy and enthalpy, whether or not the reaction will reach equilibrium. **(3 marks)**

4. Given the reacting system:

$$H_{2(g)} + I_{2(g)} \rightleftarrows 2HI_{(g)} \qquad K_{eq} = 64$$

Equal moles of H_2, I_2 and HI are placed in a 1.0 L container. Use calculations to determine the direction the reaction will proceed in order to reach equilibrium. **(3 marks)**

5. After a 50.0 mL sample of a saturated solution of Ag_2SO_4 was heated to dryness, 7.2×10^{-4} g of solid Ag_2SO_4 remained. What is the value of K_{sp} for Ag_2SO_4 ? **(5 marks)**

OVER

6. a) Write an equation to represent the predominant reaction when $HC_2O_4^-$ is mixed with HSO_4^- . **(1 mark)**

b) Justify your statement by comparing K_a values. **(1 mark)**

c) Identify a conjugate acid-base pair. **(1 mark)**

d) Predict whether the equilibrium will favour the formation of reactants or products. Explain. **(2 marks)**

7. Write an equation representing the ionization of water and state both ion concentrations that exist for pure water to have a $pH = 7.20$. **(3 marks)**

8. Calculate the pH of 0.25 M $NaHCO_3$, a basic salt. **(5 marks)**

9. Explain why the action of a buffer solution is limited. **(2 marks)**

_____

_____

_____

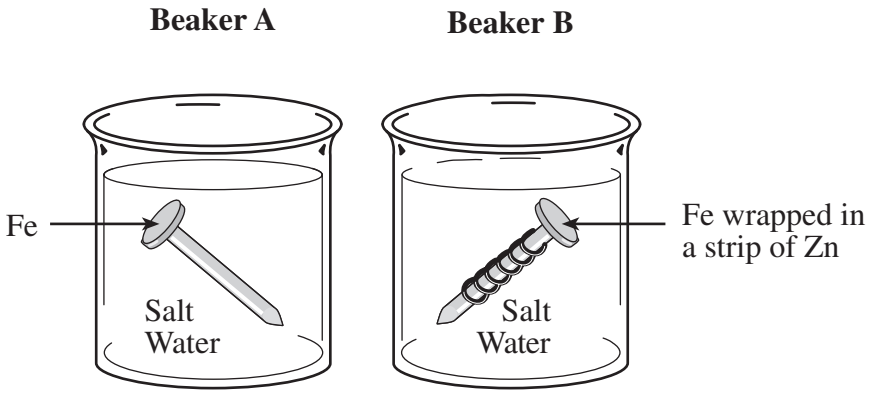
OVER

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

$$H_2S + CrO_4^{2-} \rightarrow S_8 + Cr^{3+} \qquad \text{(acidic)}$$

11. An excess of copper solid is dropped into a solution which contains $AgNO_3$, $Fe(NO_3)_3$ and $Zn(NO_3)_2$. Write the equations for any reduction half-reactions that occur over time under standard conditions. **(2 marks)**

12. Consider the following diagrams:



a) Predict what should happen to the Fe in Beaker A. **(1 mark)**

Prediction: _____

_____

b) Predict what should happen to the Fe in Beaker B. Explain. **(2 marks)**

Prediction: _____

_____

Explanation: _____

_____

END OF EXAMINATION

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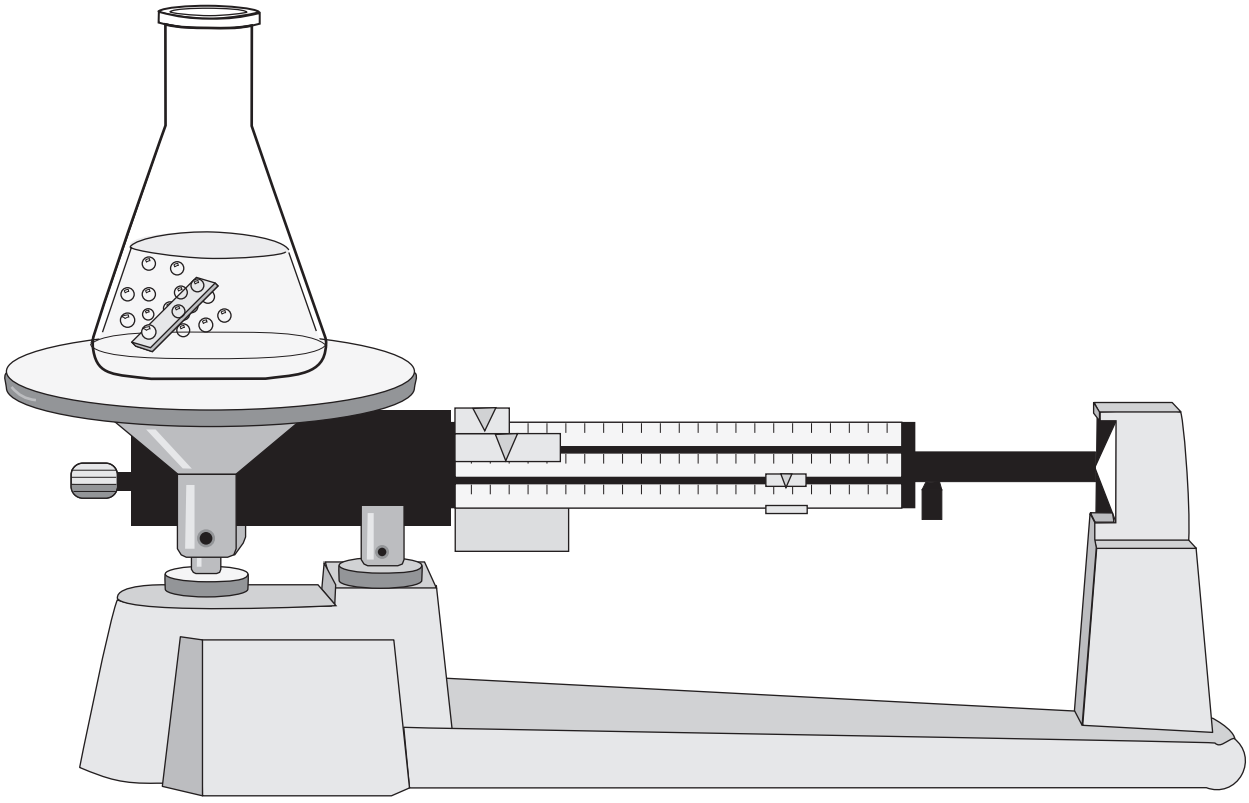
Data Booklet

CHEMISTRY 12

Work done in this booklet
will not be marked.



Revised January 2000

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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