INSERT STUDENT I.D. NUMBER (PEN)

STICKER IN THIS SPACE

JANUARY 2000

PROVINCIAL EXAMINATION

MINISTRY OF EDUCATION

CHEMISTRY 12

GENERAL INSTRUCTIONS

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

2. Ensure that in addition to this examination booklet, you have a **Data Booklet** and an **Examination Response Form**. Follow the directions on the front of the Response Form.

3. **Disqualification** from the examination will result if you bring books, paper, notes or unauthorized electronic devices into the examination room.

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

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

6. When instructed to open this booklet, **check the numbering of the pages** to ensure that they are numbered in sequence from page one to the last page, which is identified by

   END OF EXAMINATION.

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

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CHEMISTRY 12 PROVINCIAL EXAMINATION

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

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

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

   No other reference materials or tables are allowed.

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

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

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

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PART A: MULTIPLE CHOICE

Value: 48 marks **Suggested Time: 70 minutes**

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

1. Which of the following is most likely to have the **greatest** reaction rate at room temperature?

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

   B. $2Ag^{+}_{(aq)} + CrO_4^{2-}{}_{(aq)} \rightarrow Ag_2CrO_{4(s)}$

   C. $Pb_{(s)} + 2HCl_{(aq)} \rightarrow PbCl_{2(aq)} + H_{2(g)}$

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

2. Consider the following reaction involving 1.0 g of powdered zinc:

$$Zn_{(s)} + 2HCl_{(aq)} \rightarrow ZnCl_{2(aq)} + H_{2(g)}$$

Trial	Temperature (°C)	Concentration of HCl
1	40	3.0
2	20	3.0
3	40	6.0

   The rates, in order of fastest to slowest, are

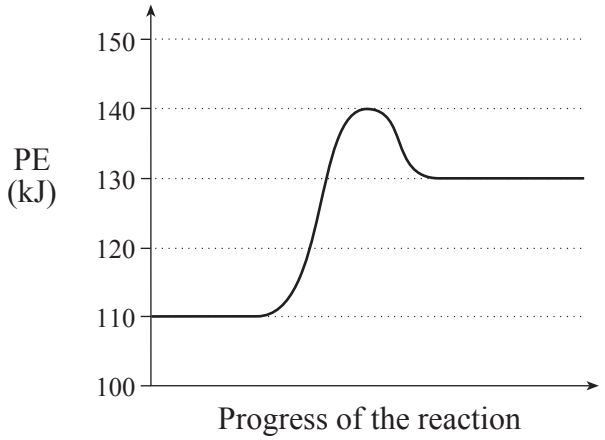
   A. 1, 2, 3
   B. 2, 1, 3
   C. 3, 1, 2
   D. 3, 2, 1

3. Activation energy can be described as the

   A. energy of motion.
   B. energy of the activated complex.
   C. energy difference between the reactants and the products.
   D. energy difference between the reactants and the activated complex.

OVER

4. Consider the following potential energy diagram for a reversible reaction:



Which of the following describes the system above?

	Reaction	Activation Energy (kJ)	ΔH (kJ)
A.	reverse	10	–20
B.	reverse	10	–30
C.	forward	30	+10
D.	forward	20	+30

5. Increasing the temperature of a reaction increases the reaction rate by

I.	increasing frequency of collisions
II.	increasing the kinetic energy of collision
III.	decreasing the potential energy of collision

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

6. What effect does a catalyst have on a reaction?

   A. It changes the ΔH of a reaction.
   B. It increases the kinetic energy of the reactants.
   C. It decreases the potential energy of the products.
   D. It provides a reaction mechanism with a lower activation energy.

7. Consider the following equilibrium:

$$N_{2(g)} + 2\,O_{2(g)} \rightleftarrows 2NO_{2(g)}$$

   Equal moles of N_2 and O_2 are added, under certain conditions, to a closed container. Which of the following describes the changes in the reverse reaction which occur as the system proceeds toward equilibrium?

	Rate of Reverse Reaction	$[NO_2]$
A.	increases	increases
B.	decreases	increases
C.	increases	decreases
D.	decreases	decreases

8. A chemical equilibrium is described as "dynamic" because

   A. maximum randomness has been achieved.
   B. the pressure and temperature do not change.
   C. both reactants and products continue to form.
   D. the concentrations of chemical species remain constant.

9. Which of the following reactions results in an entropy increase?

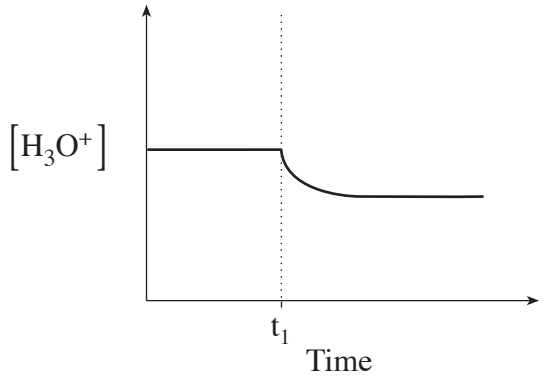
   A. $2C_{(s)} + O_{2(g)} \rightarrow 2CO_{(g)}$
   B. $N_{2(g)} + 2H_{2(g)} \rightarrow N_2H_{4(\ell)}$
   C. $2SO_{2(g)} + O_{2(g)} \rightarrow 2SO_{3(g)}$
   D. $Ag^+_{(aq)} + Cl^-_{(aq)} \rightarrow AgCl_{(s)}$

OVER

10. Consider the following equilibrium:

$$CH_3COOH_{(aq)} + H_2O_{(\ell)} \rightleftarrows CH_3COO^-_{(aq)} + H_3O^+_{(aq)} + \text{heat}$$

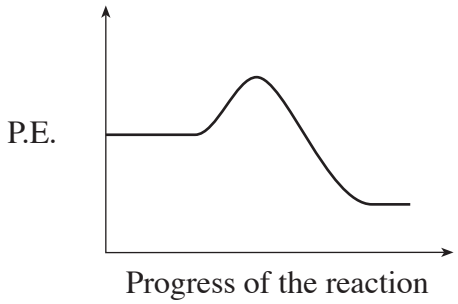
A stress was applied at time t_1 and the data was plotted on the following graph:



The stress that was imposed at time t_1 is the result of

A. the addition of HCl.
B. decreasing the temperature.
C. the addition of $NaCH_3COO$.
D. increasing the volume of the container.

11. Consider the following potential energy diagram for an equilibrium system:



When the temperature of the system is increased, the equilibrium shifts to the

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

12. What is the K_{eq} expression for the following equilibrium?

$$3Fe_{(s)} + 4H_2O_{(g)} \rightleftarrows Fe_3O_{4(s)} + 4H_{2(g)}$$

A. $K_{eq} = [H_2]^4$

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

C. $K_{eq} = \dfrac{[H_2]^4}{[H_2O]^4}$

D. $K_{eq} = \dfrac{[Fe_3O_4][H_2]^4}{[Fe]^3[H_2O]^4}$

13. Consider the following equilibrium:

$$2O_{3(g)} \rightleftarrows 3O_{2(g)} \qquad K_{eq} = 65$$

Initially, 0.10 mole of O_3 and 0.10 mole of O_2 are placed in a 1.0 L container. Which of the following describes the changes in concentrations as the reaction proceeds toward equilibrium?

	$[O_3]$	$[O_2]$
A.	decreases	decreases
B.	decreases	increases
C.	increases	decreases
D.	increases	increases

14. Which of the following does **not** define solubility?

A. the concentration of solute in a saturated solution
B. the moles of solute dissolved in a given volume of solution
C. the maximum mass of solute that can dissolve in a given volume of solution
D. the minimum moles of solute needed to produce one litre of a saturated solution

OVER

15. The ion concentrations in $0.25\,M\ Al_2(SO_4)_3$ are

	$[Al^{3+}]$	$[SO_4{}^{2-}]$
A.	0.25 M	0.25 M
B.	0.50 M	0.75 M
C.	0.75 M	0.50 M
D.	0.10 M	0.15 M

16. Which of the following will **not** produce a precipitate when equal volumes of $0.20\,M$ solutions are combined?

A. KOH and $CaCl_2$

B. $Zn(NO_3)_2$ and K_3PO_4

C. $Sr(OH)_2$ and $(NH_4)_2S$

D. Na_2SO_4 and $Pb(NO_3)_2$

17. What is observed when H_2SO_4 is added to a saturated solution of $CaSO_4$?

A. the pH increases

B. the $[Ca^{2+}]$ increases

C. bubbles of H_2 are given off

D. additional $CaSO_4$ precipitates

18. The solubility of $CdS = 2.8 \times 10^{-14}$. The value of K_{sp} is

A. 7.8×10^{-28}

B. 2.8×10^{-14}

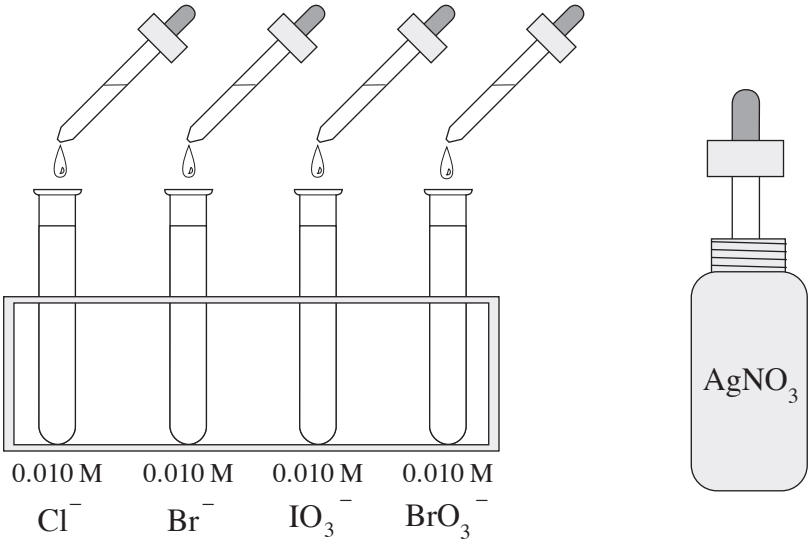
C. 5.6×10^{-14}

D. 1.7×10^{-7}

19. How many moles of solute are dissolved in 200.0 mL of a saturated solution of FeS?

A. 1.2×10^{-19}
B. 6.0×10^{-19}
C. 1.5×10^{-10}
D. 7.7×10^{-10}

20. Consider the following 10.0 mL solutions:



Equal moles of $AgNO_3$ are added to each solution. It is observed that a precipitate forms in all but one solution. Which solution does **not** form a precipitate?

A. Cl^-
B. Br^-
C. IO_3^-
D. BrO_3^-

21. Which of the following could dissolve a precipitate of CaC_2O_4 in a saturated solution of CaC_2O_4 ?

A. NaOH
B. CaC_2O_4
C. $H_2C_2O_4$
D. $Ca(NO_3)_2$

OVER

22. Which of the following is a general property of bases?

A. taste sour
B. turn litmus red
C. conduct electric current in solution
D. concentration of H_3O^+ is greater than concentration of OH^-

23. Water will act as an acid with which of the following?

I.	H_2CO_3
II.	HCO_3^-
III.	CO_3^{2-}

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

24. Which of the following 1.0 M solutions will have the greatest electrical conductivity?

A. HI
B. H_2S
C. HCN
D. H_3PO_4

25. An acid is added to water and a new equilibrium is established.
The new equilibrium can be described by

A. $pH < pOH$ and $K_w = 1 \times 10^{-14}$
B. $pH < pOH$ and $K_w < 1 \times 10^{-14}$
C. $pH > pOH$ and $K_w = 1 \times 10^{-14}$
D. $pH > pOH$ and $K_w > 1 \times 10^{-14}$

26. Consider the following equilibrium:

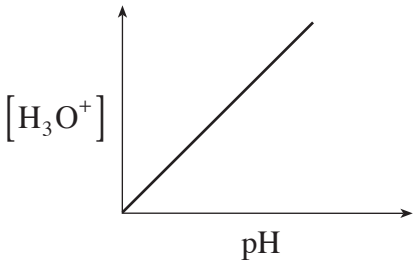
$$2H_2O_{(\ell)} + \text{energy} \rightleftarrows H_3O^+_{(aq)} + OH^-_{(aq)}$$

The $\left[H_3O^+\right]$ will decrease and the K_w will remain constant when

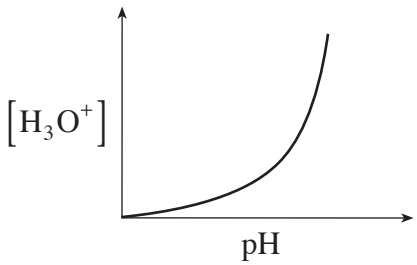
A. a strong acid is added.
B. a strong base is added.
C. the temperature is increased.
D. the temperature is decreased.

27. Which of the following graphs describes the relationship between $\left[H_3O^+\right]$ and pH ?

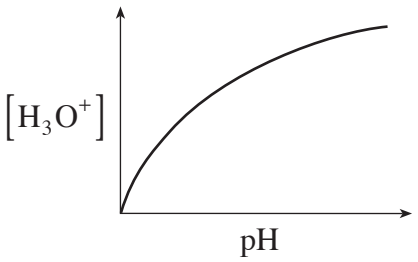
A.



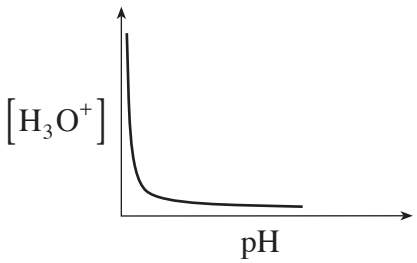
B.



C.



D.



28. When the $\left[H_3O^+\right]$ in a solution is increased to twice the original concentration, the change in pH could be from

A. 1.7 to 1.4
B. 2.0 to 4.0
C. 5.0 to 2.5
D. 8.5 to 6.5

OVER

29. The relationship $\frac{\left[H_2P_2O_7^{2-}\right]\left[H_3O^+\right]}{\left[H_3P_2O_7^-\right]}$ is the

A. K_a for $H_3P_2O_7^-$
B. K_b for $H_3P_2O_7^-$
C. K_a for $H_2P_2O_7^{2-}$
D. K_b for $H_2P_2O_7^{2-}$

30. Which of the following describes the relationship between acid strength and K_a value for weak acids?

	Acid Strength	K_a
A.	increases	increases
B.	increases	decreases
C.	decreases	increases
D.	decreases	remains constant

31. The value of K_b for HPO_4^{2-} is

A. 2.2×10^{-13}
B. 6.2×10^{-8}
C. 1.6×10^{-7}
D. 4.5×10^{-2}

32. Which of the following 1.0 M solutions would have a pH greater than 7.00?

A. HCN
B. KNO_3
C. NH_4Cl
D. $NaCH_3COO$

33. What is the pH at the transition point for an indicator with a K_a of 2.5×10^{-4} ?

A. 2.5×10^{-4}
B. 3.60
C. 7.00
D. 10.40

34. What volume of 0.100 M NaOH is required to completely neutralize 15.00 mL of 0.100 M H_3PO_4 ?

A. 5.00 mL
B. 15.0 mL
C. 30.0 mL
D. 45.0 mL

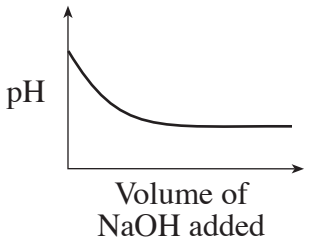
35. What is the pH of the solution formed when 0.060 moles NaOH is added to 1.00 L of 0.050 M HCl?

A. 2.00
B. 7.00
C. 12.00
D. 12.78

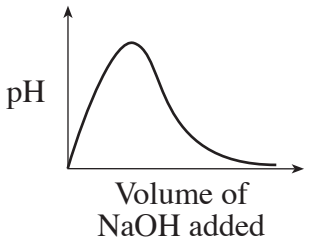
OVER

36. Which of the following graphs describes the relationship between the pH of a buffer and the volume of NaOH added to the buffer?

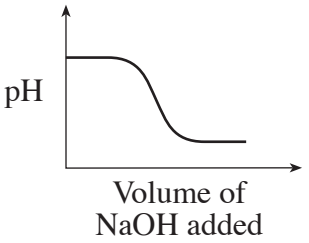
A.



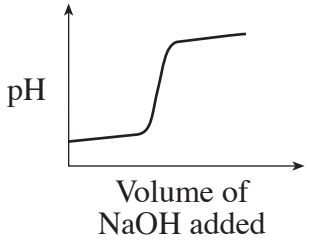
B.



C.



D.



37. A gas which is produced by internal combustion engines and contributes to the formation of acid rain is

A. H_2
B. O_3
C. CH_4
D. NO_2

38. Which of the following represents a redox reaction?

A. $CaCO_3 \rightarrow CaO + CO_2$
B. $SiCl_4 + 2Mg \rightarrow Si + 2MgCl_2$
C. $2NaOH + H_2SO_4 \rightarrow 2H_2O + Na_2SO_4$
D. $AgBr + 2S_2O_3^{2-} \rightarrow Ag(S_2O_3)_2^{3-} + Br^-$

39. Consider the following reaction:

$$TiCl_4 + O_2 \rightarrow TiO_2 + 2Cl_2$$

Each oxygen atom is

A. reduced and loses $2e^-$
B. reduced and gains $2e^-$
C. oxidized and loses $2e^-$
D. oxidized and gains $2e^-$

40. When NO_2 acts as a reducing agent, a possible product is

A. NO
B. N_2O
C. N_2O_4
D. N_2O_5

41. Which of the following $1.0\,M$ solutions will react spontaneously with lead?

A. KCl
B. $CuCl_2$
C. $ZnCl_2$
D. $MgCl_2$

42. Consider the following redox reaction:

$$I_2 + 2S_2O_3^{2-} \rightarrow S_4O_6^{2-} + 2I^-$$

In a titration, $40.00\,mL$ of $Na_2S_2O_3$ is needed to react completely with 4.0×10^{-3} mol I_2. What is the concentration of $Na_2S_2O_3$?

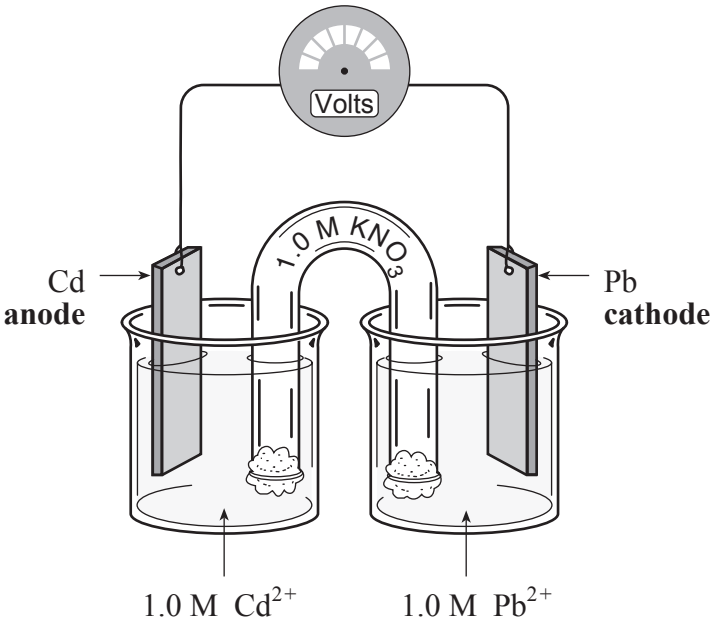
A. $0.10\,M$
B. $0.16\,M$
C. $0.20\,M$
D. $0.32\,M$

OVER

43. In an operating electrochemical cell the function of a salt bridge is to

A. allow hydrolysis to occur.
B. allow a non-spontaneous reaction to occur.
C. permit the migration of ions within the cell.
D. transfer electrons from the cathode to the anode.

Use the following diagram to answer questions 44 and 45.



E° cell = 0.27 V

44. As the cell operates, electrons flow toward

A. the Pb electrode, where Pb is oxidized.
B. the Cd electrode, where Cd is oxidized.
C. the Pb electrode, where Pb^{2+} is reduced.
D. the Cd electrode, where Cd^{2+} is reduced.

45. The E° value for the reduction of Cd^{2+} is

A. −0.40 V
B. −0.27 V
C. +0.14 V
D. +0.40 V

46. The following reaction occurs in an electrochemical cell:

$$3Cu^{2+} + 2Cr \rightarrow 2Cr^{3+} + 3Cu$$

The $E°$ for the cell is

A. 0.40 V
B. 0.75 V
C. 1.08 V
D. 2.50 V

47. During the corrosion of magnesium, the anode reaction is

A. $Mg \rightarrow Mg^{2+} + 2e^-$
B. $Mg^{2+} + 2e^- \rightarrow Mg$
C. $4OH^- \rightarrow O_2 + 2H_2O + 4e^-$
D. $O_2 + 2H_2O + 4e^- \rightarrow 4OH^-$

48. A molten binary salt, $ZnCl_2$, undergoes electrolysis. The cathode reaction is

A. $Zn \rightarrow Zn^{2+} + 2e^-$
B. $2Cl^- \rightarrow Cl_2 + 2e^-$
C. $Cl_2 + 2e^- \rightarrow 2Cl^-$
D. $Zn^{2+} + 2e^- \rightarrow Zn$

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

OVER

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. A student wishes to monitor the rate of the following reaction:

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

Identify **two** different properties that could be used to monitor the rate of the reaction. Describe and explain the changes that would occur. **(2 marks)**

Property 1: _____

Change and Explanation: _____

_____

Property 2: _____

Change and Explanation: _____

_____

2. Consider the following reaction for the formation of HCl in the presence of light.

$$Cl_2 + CHCl_3 \rightarrow HCl + CCl_4$$

The following is the proposed reaction mechanism:

Step 1	$Cl_2 \rightarrow Cl + Cl$
Step 2	**?**
Step 3	$Cl + CCl_3 \rightarrow CCl_4$

Determine Step 2 of the reaction mechanism. **(2 marks)**

3. Consider the following equilibrium:

$$\underset{\text{(yellow)}}{HInd} + H_2O \rightleftarrows H_3O^+ + \underset{\text{(blue)}}{Ind^-}$$

The system is yellow and turns blue on the addition of $NaOH$. In terms of the forward and reverse reaction rates, explain why this shift occurs. **(2 marks)**

_____

_____

_____

_____

_____

OVER

4. Consider the following equilibrium:

$$Fe^{3+}_{(aq)} + SCN^{-}_{(aq)} \rightleftarrows FeSCN^{2+}_{(aq)}$$

Initially, 50.0 mL of 0.10 M Fe^{3+} is added to 30.0 mL of 0.20 M SCN^{-}.
At equilibrium, the concentration of $FeSCN^{2+}$ is found to be 0.050 M.
Calculate the K_{eq} for the reaction. **(4 marks)**

5. a) Write the balanced formula equation for the reaction between $Na_3PO_{4(aq)}$ and $CuCl_{2(aq)}$. **(1 mark)**

b) Write the net ionic equation for the reaction between $Na_3PO_{4(aq)}$ and $CuCl_{2(aq)}$. **(1 mark)**

6. A saturated solution of nickel carbonate, $NiCO_3$, contains 0.090 g in 2.0 L of solution. Calculate K_{sp} for $NiCO_3$. **(3 marks)**

7. Define the term *amphiprotic*. Give an example of an ion which is amphiprotic. **(2 marks)**

Definition: _____

_____

Example: _____

OVER

8. A $0.0200\,M$ solution of methylamine, CH_3NH_2, has a $pH = 11.40$.
Calculate the K_b for methylamine. **(4 marks)**

9. A titration was performed by adding $0.115\,M$ NaOH to a $25.00\,mL$ sample of H_2SO_4.
Calculate the $[H_2SO_4]$ from the following data. **(3 marks)**

	Trial #1	Trial #2	Trial #3
Initial volume of NaOH (mL)	4.00	17.05	8.00
Final volume of NaOH (mL)	17.05	28.00	19.05

10. a) Indicate in the blank spaces on the following chart whether or not a reaction will occur when the metals are added to aqueous ions. **(1 mark)**

metal / ion	Pd	Rh	Pt
Pd^{2+}			
Rh^{2+}	no reaction		no reaction
Pt^{2+}	reaction	reaction	

b) List the oxidizing agents in order of strongest to weakest. **(1 mark)**

OVER

11. Balance the following redox reaction in **basic** solution: **(4 marks)**

$$Au + Cl^- + O_2 \rightarrow AuCl_4^- + OH^- \qquad \text{(basic)}$$

12. Draw and label a simple electrolytic cell capable of electroplating an inert electrode with silver.
(2 marks)

END OF EXAMINATION

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

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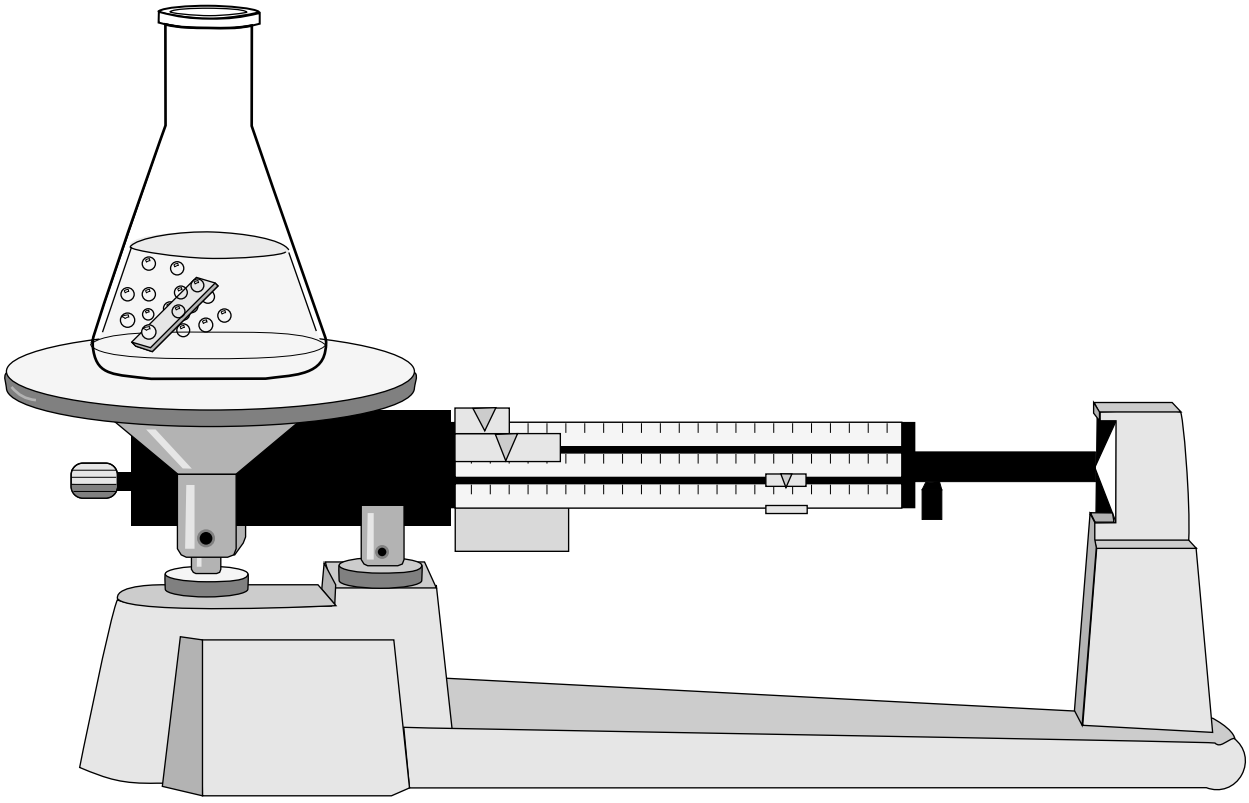

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Revised January 2000

CONTENTS

REFERENCE

D.R. Lide, *CRC Handbook of Chemistry and Physics*, 80th edition, CRC Press, Boca Raton, 1999.

PERIODIC TABLE OF THE ELEMENTS

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1 **H** Hydrogen 1.0																	2 **He** Helium 4.0
3 **Li** Lithium 6.9	4 **Be** Beryllium 9.0											5 **B** Boron 10.8	6 **C** Carbon 12.0	7 **N** Nitrogen 14.0	8 **O** Oxygen 16.0	9 **F** Fluorine 19.0	10 **Ne** Neon 20.2
11 **Na** Sodium 23.0	12 **Mg** Magnesium 24.3											13 **Al** Aluminum 27.0	14 **Si** Silicon 28.1	15 **P** Phosphorus 31.0	16 **S** Sulphur 32.1	17 **Cl** Chlorine 35.5	18 **Ar** Argon 39.9
19 **K** Potassium 39.1	20 **Ca** Calcium 40.1	21 **Sc** Scandium 45.0	22 **Ti** Titanium 47.9	23 **V** Vanadium 50.9	24 **Cr** Chromium 52.0	25 **Mn** Manganese 54.9	26 **Fe** Iron 55.8	27 **Co** Cobalt 58.9	28 **Ni** Nickel 58.7	29 **Cu** Copper 63.5	30 **Zn** Zinc 65.4	31 **Ga** Gallium 69.7	32 **Ge** Germanium 72.6	33 **As** Arsenic 74.9	34 **Se** Selenium 79.0	35 **Br** Bromine 79.9	36 **Kr** Krypton 83.8
37 **Rb** Rubidium 85.5	38 **Sr** Strontium 87.6	39 **Y** Yttrium 88.9	40 **Zr** Zirconium 91.2	41 **Nb** Niobium 92.9	42 **Mo** Molybdenum 95.9	43 **Tc** Technetium (98)	44 **Ru** Ruthenium 101.1	45 **Rh** Rhodium 102.9	46 **Pd** Palladium 106.4	47 **Ag** Silver 107.9	48 **Cd** Cadmium 112.4	49 **In** Indium 114.8	50 **Sn** Tin 118.7	51 **Sb** Antimony 121.8	52 **Te** Tellurium 127.6	53 **I** Iodine 126.9	54 **Xe** Xenon 131.3
55 **Cs** Cesium 132.9	56 **Ba** Barium 137.3	57 **La** Lanthanum 138.9	72 **Hf** Hafnium 178.5	73 **Ta** Tantalum 180.9	74 **W** Tungsten 183.8	75 **Re** Rhenium 186.2	76 **Os** Osmium 190.2	77 **Ir** Iridium 192.2	78 **Pt** Platinum 195.1	79 **Au** Gold 197.0	80 **Hg** Mercury 200.6	81 **Tl** Thallium 204.4	82 **Pb** Lead 207.2	83 **Bi** Bismuth 209.0	84 **Po** Polonium (209)	85 **At** Astatine (210)	86 **Rn** Radon (222)
87 **Fr** Francium (223)	88 **Ra** Radium (226)	89 **Ac** Actinium (227)	104 **Rf** Rutherfordium (261)	105 **Db** Dubnium (262)	106 **Sg** Seaborgium (263)	107 **Bh** Bohrium (262)	108 **Hs** Hassium (265)	109 **Mt** Meitnerium (266)									

14 **Si** Silicon 28.1 — Atomic Number, Symbol, Name, Atomic Mass

58	59	60	61	62	63	64	65	66	67	68	69	70	71
Ce Cerium 140.1	**Pr** Praseodymium 140.9	**Nd** Neodymium 144.2	**Pm** Promethium (145)	**Sm** Samarium 150.4	**Eu** Europium 152.0	**Gd** Gadolinium 157.3	**Tb** Terbium 158.9	**Dy** Dysprosium 162.5	**Ho** Holmium 164.9	**Er** Erbium 167.3	**Tm** Thulium 168.9	**Yb** Ytterbium 173.0	**Lu** Lutetium 175.0
90 **Th** Thorium 232.0	91 **Pa** Protactinium 231.0	92 **U** Uranium 238.0	93 **Np** Neptunium (237)	94 **Pu** Plutonium (244)	95 **Am** Americium (243)	96 **Cm** Curium (247)	97 **Bk** Berkelium (247)	98 **Cf** Californium (251)	99 **Es** Einsteinium (252)	100 **Fm** Fermium (257)	101 **Md** Mendelevium (258)	102 **No** Nobelium (259)	103 **Lr** Lawrencium (262)

Based on mass of C^{12} at 12.00.

Values in parentheses are the masses of the most stable or best known isotopes for elements which do not occur naturally.

ATOMIC MASSES OF THE ELEMENTS

Based on mass of C^{12} at 12.00.
Values in parentheses are the mass number of the most stable or best known isotopes for elements that do not occur naturally.

Element	Symbol	Atomic Number	Atomic Mass
Actinium	Ac	89	(227)
Aluminum	Al	13	27.0
Americium	Am	95	(243)
Antimony	Sb	51	121.8
Argon	Ar	18	39.9
Arsenic	As	33	74.9
Astatine	At	85	(210)
Barium	Ba	56	137.3
Berkelium	Bk	97	(247)
Beryllium	Be	4	9.0
Bismuth	Bi	83	209.0
Boron	B	5	10.8
Bromine	Br	35	79.9
Cadmium	Cd	48	112.4
Calcium	Ca	20	40.1
Californium	Cf	98	(251)
Carbon	C	6	12.0
Cerium	Ce	58	140.1
Cesium	Cs	55	132.9
Chlorine	Cl	17	35.5
Chromium	Cr	24	52.0
Cobalt	Co	27	58.9
Copper	Cu	29	63.5
Curium	Cm	96	(247)
Dubnium	Db	105	(262)
Dysprosium	Dy	66	162.5
Einsteinium	Es	99	(252)
Erbium	Er	68	167.3
Europium	Eu	63	152.0
Fermium	Fm	100	(257)
Fluorine	F	9	19.0
Francium	Fr	87	(223)
Gadolinium	Gd	64	157.3
Gallium	Ga	31	69.7
Germanium	Ge	32	72.6
Gold	Au	79	197.0
Hafnium	Hf	72	178.5
Helium	He	2	4.0
Holmium	Ho	67	164.9
Hydrogen	H	1	1.0
Indium	In	49	114.8
Iodine	I	53	126.9
Iridium	Ir	77	192.2
Iron	Fe	26	55.8
Krypton	Kr	36	83.8
Lanthanum	La	57	138.9
Lawrencium	Lr	103	(262)
Lead	Pb	82	207.2
Lithium	Li	3	6.9
Lutetium	Lu	71	175.0
Magnesium	Mg	12	24.3
Manganese	Mn	25	54.9
Mendelevium	Md	101	(258)
Mercury	Hg	80	200.6
Molybdenum	Mo	42	95.9
Neodymium	Nd	60	144.2
Neon	Ne	10	20.2
Neptunium	Np	93	(237)
Nickel	Ni	28	58.7
Niobium	Nb	41	92.9
Nitrogen	N	7	14.0
Nobelium	No	102	(259)
Osmium	Os	76	190.2
Oxygen	O	8	16.0
Palladium	Pd	46	106.4
Phosphorus	P	15	31.0
Platinum	Pt	78	195.1
Plutonium	Pu	94	(244)
Polonium	Po	84	(209)
Potassium	K	19	39.1
Praseodymium	Pr	59	140.9
Promethium	Pm	61	(145)
Protactinium	Pa	91	231.0
Radium	Ra	88	(226)
Radon	Rn	86	(222)
Rhenium	Re	75	186.2
Rhodium	Rh	45	102.9
Rubidium	Rb	37	85.5
Ruthenium	Ru	44	101.1
Rutherfordium	Rf	104	(261)
Samarium	Sm	62	150.4
Scandium	Sc	21	45.0
Selenium	Se	34	79.0
Silicon	Si	14	28.1
Silver	Ag	47	107.9
Sodium	Na	11	23.0
Strontium	Sr	38	87.6
Sulphur	S	16	32.1
Tantalum	Ta	73	180.9
Technetium	Tc	43	(98)
Tellurium	Te	52	127.6
Terbium	Tb	65	158.9
Thallium	Tl	81	204.4
Thorium	Th	90	232.0
Thulium	Tm	69	168.9
Tin	Sn	50	118.7
Titanium	Ti	22	47.9
Tungsten	W	74	183.8
Uranium	U	92	238.0
Vanadium	V	23	50.9
Xenon	Xe	54	131.3
Ytterbium	Yb	70	173.0
Yttrium	Y	39	88.9
Zinc	Zn	30	65.4
Zirconium	Zr	40	91.2

NAMES, FORMULAE, AND CHARGES OF SOME COMMON IONS

* *Aqueous solutions are readily oxidized by air.*
** *Not stable in aqueous solutions.*

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

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

SOLUBILITY OF COMMON COMPOUNDS IN WATER

The term soluble here means > 0.1 mol/L at 25°C.

Negative Ions (Anions)	Positive Ions (Cations)	Solubility of Compounds
All	Alkali ions: Li^+, Na^+, K^+, Rb^+, Cs^+, Fr^+	Soluble
All	Hydrogen ion: H^+	Soluble
All	Ammonium ion: NH_4^+	Soluble
Nitrate, NO_3^-	All	Soluble
Chloride, Cl^- or Bromide, Br^- or Iodide, I^-	All others	Soluble
	Ag^+, Pb^{2+}, Cu^+	Low Solubility
Sulphate, SO_4^{2-}	All others	Soluble
	Ag^+, Ca^{2+}, Sr^{2+}, Ba^{2+}, Pb^{2+}	Low Solubility
Sulphide, S^{2-}	Alkali ions, H^+, NH_4^+, Be^{2+}, Mg^{2+}, Ca^{2+}, Sr^{2+}, Ba^{2+}	Soluble
	All others	Low Solubility
Hydroxide, OH^-	Alkali ions, H^+, NH_4^+, Sr^{2+}	Soluble
	All others	Low Solubility
Phosphate, PO_4^{3-} or Carbonate, CO_3^{2-} or Sulphite, SO_3^{2-}	Alkali ions, H^+, NH_4^+	Soluble
	All others	Low Solubility

SOLUBILITY PRODUCT CONSTANTS AT 25°C

Name	Formula	K_{sp}
Barium carbonate	$BaCO_3$	2.6×10^{-9}
Barium chromate	$BaCrO_4$	1.2×10^{-10}
Barium sulphate	$BaSO_4$	1.1×10^{-10}
Calcium carbonate	$CaCO_3$	5.0×10^{-9}
Calcium oxalate	CaC_2O_4	2.3×10^{-9}
Calcium sulphate	$CaSO_4$	7.1×10^{-5}
Copper(I) iodide	CuI	1.3×10^{-12}
Copper(II) iodate	$Cu(IO_3)_2$	6.9×10^{-8}
Copper(II) sulphide	CuS	6.0×10^{-37}
Iron(II) hydroxide	$Fe(OH)_2$	4.9×10^{-17}
Iron(II) sulphide	FeS	6.0×10^{-19}
Iron(III) hydroxide	$Fe(OH)_3$	2.6×10^{-39}
Lead(II) bromide	$PbBr_2$	6.6×10^{-6}
Lead(II) chloride	$PbCl_2$	1.2×10^{-5}
Lead(II) iodate	$Pb(IO_3)_2$	3.7×10^{-13}
Lead(II) iodide	PbI_2	8.5×10^{-9}
Lead(II) sulphate	$PbSO_4$	1.8×10^{-8}
Magnesium carbonate	$MgCO_3$	6.8×10^{-6}
Magnesium hydroxide	$Mg(OH)_2$	5.6×10^{-12}
Silver bromate	$AgBrO_3$	5.3×10^{-5}
Silver bromide	$AgBr$	5.4×10^{-13}
Silver carbonate	Ag_2CO_3	8.5×10^{-12}
Silver chloride	$AgCl$	1.8×10^{-10}
Silver chromate	Ag_2CrO_4	1.1×10^{-12}
Silver iodate	$AgIO_3$	3.2×10^{-8}
Silver iodide	AgI	8.5×10^{-17}
Strontium carbonate	$SrCO_3$	5.6×10^{-10}
Strontium fluoride	SrF_2	4.3×10^{-9}
Strontium sulphate	$SrSO_4$	3.4×10^{-7}
Zinc sulphide	ZnS	2.0×10^{-25}

RELATIVE STRENGTHS OF BRØNSTED-LOWRY ACIDS AND BASES

in aqueous solution at room temperature.

STRENGTH OF ACID: STRONG (top) → WEAK (bottom)

STRENGTH OF BASE: WEAK (top) → STRONG (bottom)

Name of Acid	Acid		Base	K_a
Perchloric	$HClO_4$	$\rightarrow$	$H^+ + ClO_4^-$	very large
Hydriodic	HI	$\rightarrow$	$H^+ + I^-$	very large
Hydrobromic	HBr	$\rightarrow$	$H^+ + Br^-$	very large
Hydrochloric	HCl	$\rightarrow$	$H^+ + Cl^-$	very large
Nitric	HNO_3	$\rightarrow$	$H^+ + NO_3^-$	very large
Sulphuric	H_2SO_4	$\rightarrow$	$H^+ + HSO_4^-$	very large
Hydronium Ion	H_3O^+	$\rightleftarrows$	$H^+ + H_2O$	1.0
Iodic	HIO_3	$\rightleftarrows$	$H^+ + IO_3^-$	1.7×10^{-1}
Oxalic	$H_2C_2O_4$	$\rightleftarrows$	$H^+ + HC_2O_4^-$	5.9×10^{-2}
Sulphurous $(SO_2 + H_2O)$	H_2SO_3	$\rightleftarrows$	$H^+ + HSO_3^-$	1.5×10^{-2}
Hydrogen sulphate ion	HSO_4^-	$\rightleftarrows$	$H^+ + SO_4^{2-}$	1.2×10^{-2}
Phosphoric	H_3PO_4	$\rightleftarrows$	$H^+ + H_2PO_4^-$	7.5×10^{-3}
Hexaaquoiron ion, iron(III) ion	$Fe(H_2O)_6^{3+}$	$\rightleftarrows$	$H^+ + Fe(H_2O)_5(OH)^{2+}$	6.0×10^{-3}
Citric	$H_3C_6H_5O_7$	$\rightleftarrows$	$H^+ + H_2C_6H_5O_7^-$	7.1×10^{-4}
Nitrous	HNO_2	$\rightleftarrows$	$H^+ + NO_2^-$	4.6×10^{-4}
Hydrofluoric	HF	$\rightleftarrows$	$H^+ + F^-$	3.5×10^{-4}
Methanoic, formic	$HCOOH$	$\rightleftarrows$	$H^+ + HCOO^-$	1.8×10^{-4}
Hexaaquochromium ion, chromium(III) ion	$Cr(H_2O)_6^{3+}$	$\rightleftarrows$	$H^+ + Cr(H_2O)_5(OH)^{2+}$	1.5×10^{-4}
Benzoic	C_6H_5COOH	$\rightleftarrows$	$H^+ + C_6H_5COO^-$	6.5×10^{-5}
Hydrogen oxalate ion	$HC_2O_4^-$	$\rightleftarrows$	$H^+ + C_2O_4^{2-}$	6.4×10^{-5}
Ethanoic, acetic	CH_3COOH	$\rightleftarrows$	$H^+ + CH_3COO^-$	1.8×10^{-5}
Dihydrogen citrate ion	$H_2C_6H_5O_7^-$	$\rightleftarrows$	$H^+ + HC_6H_5O_7^{2-}$	1.7×10^{-5}
Hexaaquoaluminum ion, aluminum ion	$Al(H_2O)_6^{3+}$	$\rightleftarrows$	$H^+ + Al(H_2O)_5(OH)^{2+}$	1.4×10^{-5}
Carbonic $(CO_2 + H_2O)$	H_2CO_3	$\rightleftarrows$	$H^+ + HCO_3^-$	4.3×10^{-7}
Monohydrogen citrate ion	$HC_6H_5O_7^{2-}$	$\rightleftarrows$	$H^+ + C_6H_5O_7^{3-}$	4.1×10^{-7}
Hydrogen sulphite ion	HSO_3^-	$\rightleftarrows$	$H^+ + SO_3^{2-}$	1.0×10^{-7}
Hydrogen sulphide	H_2S	$\rightleftarrows$	$H^+ + HS^-$	9.1×10^{-8}
Dihydrogen phosphate ion	$H_2PO_4^-$	$\rightleftarrows$	$H^+ + HPO_4^{2-}$	6.2×10^{-8}
Boric	H_3BO_3	$\rightleftarrows$	$H^+ + H_2BO_3^-$	7.3×10^{-10}
Ammonium ion	NH_4^+	$\rightleftarrows$	$H^+ + NH_3$	5.6×10^{-10}
Hydrocyanic	HCN	$\rightleftarrows$	$H^+ + CN^-$	4.9×10^{-10}
Phenol	C_6H_5OH	$\rightleftarrows$	$H^+ + C_6H_5O^-$	1.3×10^{-10}
Hydrogen carbonate ion	HCO_3^-	$\rightleftarrows$	$H^+ + CO_3^{2-}$	5.6×10^{-11}
Hydrogen peroxide	H_2O_2	$\rightleftarrows$	$H^+ + HO_2^-$	2.4×10^{-12}
Monohydrogen phosphate ion	HPO_4^{2-}	$\rightleftarrows$	$H^+ + PO_4^{3-}$	2.2×10^{-13}
Water	H_2O	$\rightleftarrows$	$H^+ + OH^-$	1.0×10^{-14}
Hydroxide ion	OH^-	$\leftarrow$	$H^+ + O^{2-}$	very small
Ammonia	NH_3	$\leftarrow$	$H^+ + NH_2^-$	very small

ACID-BASE INDICATORS

Indicator	pH Range in Which Colour Change Occurs	Colour Change as pH Increases
Methyl violet	0.0 – 1.6	yellow to blue
Thymol blue	1.2 – 2.8	red to yellow
Orange IV	1.4 – 2.8	red to yellow
Methyl orange	3.2 – 4.4	red to yellow
Bromcresol green	3.8 – 5.4	yellow to blue
Methyl red	4.8 – 6.0	red to yellow
Chlorophenol red	5.2 – 6.8	yellow to red
Bromthymol blue	6.0 – 7.6	yellow to blue
Phenol red	6.6 – 8.0	yellow to red
Neutral red	6.8 – 8.0	red to amber
Thymol blue	8.0 – 9.6	yellow to blue
Phenolphthalein	8.2 – 10.0	colourless to pink
Thymolphthalein	9.4 – 10.6	colourless to blue
Alizarin yellow	10.1 – 12.0	yellow to red
Indigo carmine	11.4 – 13.0	blue to yellow

STANDARD REDUCTION POTENTIALS OF HALF-CELLS

Ionic concentrations are at 1M in water at 25° C.

Oxidizing Agents		Reducing Agents	E° (Volts)
$F_{2(g)} + 2e^-$	⇄	$2F^-$	+2.87
$S_2O_8^{2-} + 2e^-$	⇄	$2SO_4^{2-}$	+2.01
$H_2O_2 + 2H^+ + 2e^-$	⇄	$2H_2O$	+1.78
$MnO_4^- + 8H^+ + 5e^-$	⇄	$Mn^{2+} + 4H_2O$	+1.51
$Au^{3+} + 3e^-$	⇄	$Au_{(s)}$	+1.50
$BrO_3^- + 6H^+ + 5e^-$	⇄	$\frac{1}{2}Br_{2(\ell)} + 3H_2O$	+1.48
$ClO_4^- + 8H^+ + 8e^-$	⇄	$Cl^- + 4H_2O$	+1.39
$Cl_{2(g)} + 2e^-$	⇄	$2Cl^-$	+1.36
$Cr_2O_7^{2-} + 14H^+ + 6e^-$	⇄	$2Cr^{3+} + 7H_2O$	+1.23
$\frac{1}{2}O_{2(g)} + 2H^+ + 2e^-$	⇄	H_2O	+1.23
$MnO_{2(s)} + 4H^+ + 2e^-$	⇄	$Mn^{2+} + 2H_2O$	+1.22
$IO_3^- + 6H^+ + 5e^-$	⇄	$\frac{1}{2}I_{2(s)} + 3H_2O$	+1.20
$Br_{2(\ell)} + 2e^-$	⇄	$2Br^-$	+1.09
$AuCl_4^- + 3e^-$	⇄	$Au_{(s)} + 4Cl^-$	+1.00
$NO_3^- + 4H^+ + 3e^-$	⇄	$NO_{(g)} + 2H_2O$	+0.96
$Hg^{2+} + 2e^-$	⇄	$Hg_{(\ell)}$	+0.85
$\frac{1}{2}O_{2(g)} + 2H^+(10^{-7}\,M) + 2e^-$	⇄	H_2O	+0.82
$2NO_3^- + 4H^+ + 2e^-$	⇄	$N_2O_4 + 2H_2O$	+0.80
$Ag^+ + e^-$	⇄	$Ag_{(s)}$	+0.80
$\frac{1}{2}Hg_2^{2+} + e^-$	⇄	$Hg_{(\ell)}$	+0.80
$Fe^{3+} + e^-$	⇄	Fe^{2+}	+0.77
$O_{2(g)} + 2H^+ + 2e^-$	⇄	H_2O_2	+0.70
$MnO_4^- + 2H_2O + 3e^-$	⇄	$MnO_{2(s)} + 4OH^-$	+0.60
$I_{2(s)} + 2e^-$	⇄	$2I^-$	+0.54
$Cu^+ + e^-$	⇄	$Cu_{(s)}$	+0.52
$H_2SO_3 + 4H^+ + 4e^-$	⇄	$S_{(s)} + 3H_2O$	+0.45
$Cu^{2+} + 2e^-$	⇄	$Cu_{(s)}$	+0.34
$SO_4^{2-} + 4H^+ + 2e^-$	⇄	$H_2SO_3 + H_2O$	+0.17
$Cu^{2+} + e^-$	⇄	Cu^+	+0.15
$Sn^{4+} + 2e^-$	⇄	Sn^{2+}	+0.15
$S_{(s)} + 2H^+ + 2e^-$	⇄	$H_2S_{(g)}$	+0.14
$2H^+ + 2e^-$	⇄	$H_{2(g)}$	+0.00
$Pb^{2+} + 2e^-$	⇄	$Pb_{(s)}$	−0.13
$Sn^{2+} + 2e^-$	⇄	$Sn_{(s)}$	−0.14
$Ni^{2+} + 2e^-$	⇄	$Ni_{(s)}$	−0.26
$H_3PO_4 + 2H^+ + 2e^-$	⇄	$H_3PO_3 + H_2O$	−0.28
$Co^{2+} + 2e^-$	⇄	$Co_{(s)}$	−0.28
$Se_{(s)} + 2H^+ + 2e^-$	⇄	H_2Se	−0.40
$Cr^{3+} + e^-$	⇄	Cr^{2+}	−0.41
$2H_2O + 2e^-$	⇄	$H_2 + 2OH^-(10^{-7}\,M)$	−0.41
$Fe^{2+} + 2e^-$	⇄	$Fe_{(s)}$	−0.45
$Ag_2S_{(s)} + 2e^-$	⇄	$2Ag_{(s)} + S^{2-}$	−0.69
$Cr^{3+} + 3e^-$	⇄	$Cr_{(s)}$	−0.74
$Zn^{2+} + 2e^-$	⇄	$Zn_{(s)}$	−0.76
$Te_{(s)} + 2H^+ + 2e^-$	⇄	H_2Te	−0.79
$2H_2O + 2e^-$	⇄	$H_{2(g)} + 2OH^-$	−0.83
$Mn^{2+} + 2e^-$	⇄	$Mn_{(s)}$	−1.19
$Al^{3+} + 3e^-$	⇄	$Al_{(s)}$	−1.66
$Mg^{2+} + 2e^-$	⇄	$Mg_{(s)}$	−2.37
$Na^+ + e^-$	⇄	$Na_{(s)}$	−2.71
$Ca^{2+} + 2e^-$	⇄	$Ca_{(s)}$	−2.87
$Sr^{2+} + 2e^-$	⇄	$Sr_{(s)}$	−2.89
$Ba^{2+} + 2e^-$	⇄	$Ba_{(s)}$	−2.91
$K^+ + e^-$	⇄	$K_{(s)}$	−2.93
$Rb^+ + e^-$	⇄	$Rb_{(s)}$	−2.98
$Cs^+ + e^-$	⇄	$Cs_{(s)}$	−3.03
$Li^+ + e^-$	⇄	$Li_{(s)}$	−3.04

Overpotential Effect

Overpotential Effect

STRONG ↑ STRENGTH OF OXIDIZING AGENT ↓ WEAK

WEAK ↑ STRENGTH OF REDUCING AGENT ↓ STRONG