INSERT STUDENT I.D. NUMBER (PEN)

STICKER IN THIS SPACE

APRIL 1999

PROVINCIAL EXAMINATION

MINISTRY OF EDUCATION

CHEMISTRY 12

GENERAL INSTRUCTIONS

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

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

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

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

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

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

   END OF EXAMINATION.

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

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CHEMISTRY 12 PROVINCIAL EXAMINATION

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

		Value	Suggested Time
PART A:	48 multiple-choice questions	48	70
PART B:	11 written-response questions	32	50
	Total:	**80 marks**	**120 minutes**

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

3. The following tables can be found in the separate **Data Booklet**.

   - Periodic Table of the Elements
   - Atomic Masses of the Elements
   - Names, Formulae, and Charges of Some Common Ions
   - Solubility of Common Compounds in Water
   - Solubility Product Constants at 25°C
   - Relative Strengths of Brönsted-Lowry Acids and Bases
   - Acid-Base Indicators
   - Standard Reduction Potentials of Half-cells

   No other reference materials or tables are allowed.

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

5. The time allotted for this examination is **two hours**.

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PART A: MULTIPLE CHOICE

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

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

1. The slowest of the following reactions is

   A. $Ag^{+}_{(aq)} + Cl^{-}_{(aq)} \rightarrow AgCl_{(s)}$

   B. $H_3O^{+}_{(aq)} + OH^{-}_{(aq)} \rightarrow 2H_2O_{(\ell)}$

   C. $3Ba^{2+}_{(aq)} + 2PO_4{}^{3-}_{(aq)} \rightarrow Ba_3(PO_4)_{2(s)}$

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

2. The rate of a chemical reaction is equal to the slope of a graph with the axes labelled

	x-axis	*y*-axis
A.	time	rate
B.	mass	time
C.	volume of gas	time
D.	time	concentration

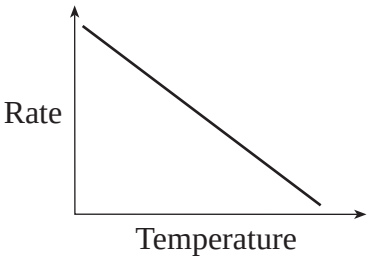
OVER

3. Consider the following reaction:

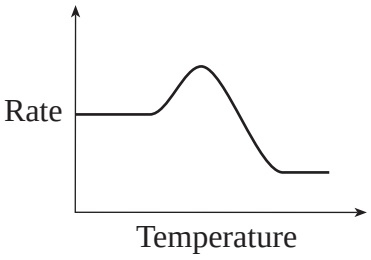
$$CH_{4(g)} + 2O_{2(g)} \rightarrow CO_{2(g)} + 2H_2O_{(g)} + \text{heat}$$

The diagram which represents the relationship between rate and temperature is:

A.



B.



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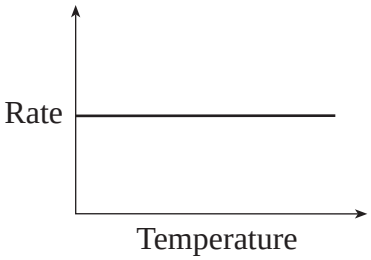
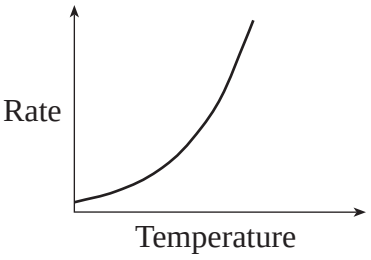


D.



4. Which of the following describes the energy of colliding particles as reacting molecules approach each other?

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

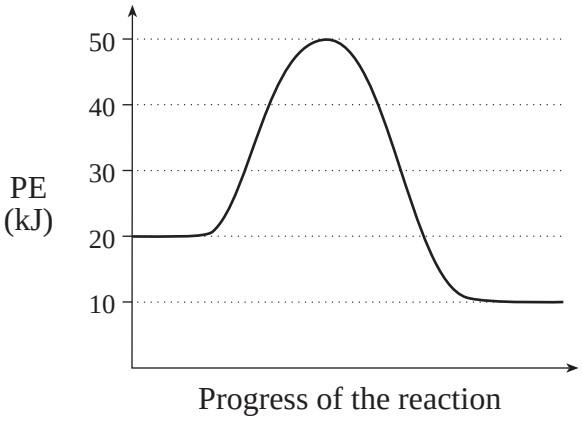
5. The average kinetic energy of colliding particles can be increased by

A. adding a catalyst.
B. increasing pressure.
C. increasing temperature.
D. increasing reactant concentration.

6. A substance that increases the rate of a chemical reaction and may be recovered unchanged at the end of the reaction is a(n)

   A. product.
   B. catalyst.
   C. activated complex.
   D. reaction intermediate.

7. Consider the following PE diagram for a reversible reaction:



Which of the following describes this reaction?

	DIRECTION	ACTIVATION ENERGY (kJ)	ΔH (kJ)
A.	reverse	30	–10
B.	forward	40	–10
C.	forward	30	+10
D.	reverse	40	+10

OVER

8. Consider the following equilibrium:

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

The equilibrium will shift to the left as a result of

A. adding a catalyst.
B. removing $NOBr$.
C. increasing the volume.
D. increasing the temperature.

9. Consider the following equilibrium:

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

When the temperature is increased, the equilibrium shifts to the

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

10. Consider the following equilibrium:

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

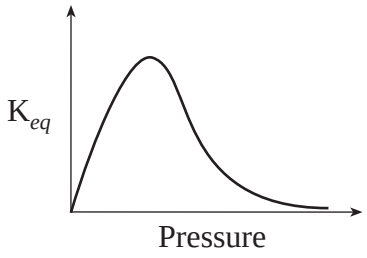
Some CO_2 is added to the equilibrium system at constant volume and a new equilibrium is established. Compared to the original equilibrium, the rates of the forward and reverse reactions for the new equilibrium have

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

11. An indication that an equilibrium system favours the products is a

A. large K_{eq}.
B. positive ΔH.
C. one step mechanism.
D. low activation energy.

12. The relationship between K_{eq} and the pressure of a gaseous equilibrium at constant temperature can be described by

A.


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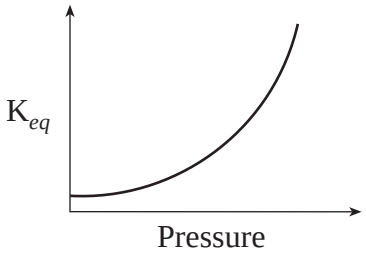

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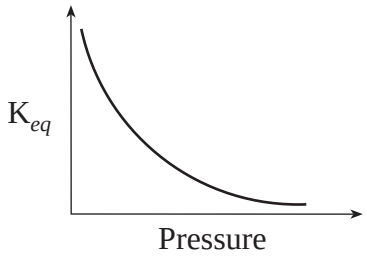
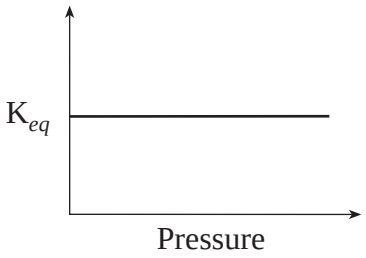


D.


13. Consider the following equilibrium:

$$2NO_{2(g)} \rightleftarrows N_2O_{4(g)}$$

A 1.00 L flask contains 0.030 mol NO_2 and 0.040 mol N_2O_4 at equilibrium.
The value of K_{eq} is

A. 0.023
B. 0.67
C. 1.3
D. 44

OVER

14. Which of the following produces a molecular solution when dissolved in water?

A. $RbClO$
B. CH_3OH
C. NH_4SCN
D. $NaCH_3COO$

15. Consider the solubility equilibrium:

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

An additional piece of solid $CaCO_3$ is added to the equilibrium above.
The rate of dissolving and rate of crystallization have

	RATE OF DISSOLVING	RATE OF CRYSTALLIZATION
A.	increased	increased
B.	increased	not changed
C.	not changed	increased
D.	not changed	not changed

16. At $25°C$, which of the following compounds would dissolve to form a saturated solution with the greatest $\left[Pb^{2+}\right]$?

A. PbI_2
B. $PbCl_2$
C. $PbBr_2$
D. $Pb(IO_3)_2$

17. When equal volumes of $0.20\,M$ $ZnSO_4$ and $0.20\,M$ $Sr(OH)_2$ are combined,

A. no precipitate forms.
B. a precipitate of only $SrSO_4$ forms.
C. a precipitate of only $Zn(OH)_2$ forms.
D. precipitates of both $SrSO_4$ and $Zn(OH)_2$ form.

18. The solubility of SnS is 3.2×10^{-3} M. The value of K_{sp} is

A. 1.0×10^{-5}
B. 3.2×10^{-3}
C. 6.4×10^{-3}
D. 5.7×10^{-2}

19. Silver chloride, $AgCl$, would be least soluble in

A. 1.0 M HCl
B. 1.0 M $NaNO_3$
C. 1.0 M $ZnCl_2$
D. 1.0 M $AgNO_3$

20. The solubility of SrF_2 is

A. 4.3×10^{-9} M
B. 6.6×10^{-5} M
C. 1.0×10^{-3} M
D. 1.6×10^{-3} M

21. Which of the following is a property of sodium hydroxide?

A. feels slippery
B. releases H_3O^+ in aqueous solution
C. changes litmus paper from blue to red
D. reacts with magnesium to produce hydrogen gas

OVER

22. The conjugate acid of $HAsO_4^{2-}$ is

A. H_3O^+

B. AsO_4^{3-}

C. H_3AsO_4

D. $H_2AsO_4^-$

23. Which of the following $0.10\,M$ solutions has the highest electrical conductivity?

A. HF

B. HCN

C. H_2CO_3

D. H_3BO_3

24. Consider the following acid-base equilibrium:

$$H_2C_6H_5O_7^- + HPO_4^{2-} \rightleftarrows HC_6H_5O_7^{2-} + H_2PO_4^-$$

In the equilibrium above,

A. products are favoured because $H_2PO_4^-$ is the weaker acid.

B. reactants are favoured because HPO_4^{2-} is the weaker acid.

C. products are favoured because $HC_6H_5O_7^{2-}$ is the weaker acid.

D. reactants are favoured because $H_2C_6H_5O_7^-$ is the weaker acid.

25. Which of the following describes the relationship between $\left[H_3O^+\right]$ and $\left[OH^-\right]$?

A. $\left[H_3O^+\right]\left[OH^-\right] = 14.00$

B. $\left[H_3O^+\right] + \left[OH^-\right] = 14.00$

C. $\left[H_3O^+\right]\left[OH^-\right] = 1.0 \times 10^{-14}$

D. $\left[H_3O^+\right] + \left[OH^-\right] = 1.0 \times 10^{-14}$

26. Consider the following equilibrium:

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

When water has a pH of 7.5, the temperature is

A. less than $25°C$ and the solution is basic.
B. less than $25°C$ and the solution is neutral.
C. greater than $25°C$ and the solution is basic.
D. greater than $25°C$ and the solution is neutral.

27. Calculate the $\left[H_3O^+\right]$ in a $0.010\,M$ solution of $Sr(OH)_2$.

A. 5.0×10^{-13} M
B. 1.0×10^{-12} M
C. 1.0×10^{-2} M
D. 2.0×10^{-2} M

28. The value of K_b for HCO_3^- is

A. 5.6×10^{-11}
B. 2.3×10^{-8}
C. 4.3×10^{-7}
D. 1.8×10^{-4}

29. The net ionic equation for the hydrolysis of NH_4ClO_4 is

A. $NH_4ClO_{4(s)} \rightleftarrows NH_4^+{}_{(aq)} + ClO_4^-{}_{(aq)}$

B. $NH_4^+{}_{(aq)} + H_2O_{(l)} \rightleftarrows NH_{3(aq)} + H_3O^+{}_{(aq)}$

C. $ClO_4^-{}_{(aq)} + H_2O_{(l)} \rightleftarrows HClO_{4(aq)} + OH^-{}_{(aq)}$

D. $NH_4^+{}_{(aq)} + ClO_4^-{}_{(aq)} \rightleftarrows NH_{3(aq)} + HClO_{4(aq)}$

OVER

30. A sample of an unknown solution is tested with the indicator chlorophenol red. The solution turns yellow on the addition of this indicator. The solution could be

A. 1.0 M KF
B. 1.0 M NaCl
C. 1.0 M Li_2SO_4
D. 1.0 M NH_4NO_3

31. Which of the following indicators has a transition point closest to the equivalence point for the titration of a weak acid by a strong base?

A. orange IV
B. thymol blue
C. methyl orange
D. bromcresol green

32. A buffer solution is formed by adding which of the following to water?

A. HCl and KOH
B. HCN and RbCN
C. NaBr and NaOH
D. HNO_3 and $LiNO_3$

33. *A solution of known concentration* is the definition of a

A. buffer solution.
B. neutral solution.
C. standard solution.
D. saturated solution.

34. Which of the following is responsible for the acidic pH of normal rainwater?

A. CO_2
B. NO_2
C. SO_2
D. NH_3

35. A solution contains a mixture of methyl orange, phenol red and thymol blue. When this solution is yellow, the pH is

A. 3.0
B. 6.0
C. 9.0
D. 12.0

36. Which of the following represents the reaction between MgO and H_2O?

A. $MgO + H_2O \rightarrow Mg(OH)_2$
B. $MgO + H_2O \rightarrow MgH_2 + O_2$
C. $MgO + H_2O \rightarrow Mg + H_2O_2$
D. $2MgO + H_2O \rightarrow 2MgOH + \frac{1}{2}O_2$

37. Which of the following represents the formation of a stronger acid as a result of oxidation?

A. $H_2SO_3 \rightarrow H_2S$
B. $HClO_4 \rightarrow HCl$
C. $H_2SO_3 \rightarrow H_2SO_4$
D. $HCO_3^- \rightarrow H_2CO_3$

38. Chlorine has an oxidation number of $+5$ in

A. $NaClO$
B. $NaClO_2$
C. $NaClO_3$
D. $NaClO_4$

OVER

39. Consider the following:

$$NO_2 \rightarrow N_2O_3$$

The nitrogen atom in each NO_2

A. loses one electron.
B. gains one electron.
C. loses two electrons.
D. gains two electrons.

40. Which of the following is the strongest oxidizing agent?

A. BrO_3^-

B. ClO_4^-

C. $S_2O_8^{2-}$

D. $Cr_2O_7^{2-}$

41. Consider the following half-reaction:

$$\underline{1}\ AsH_3 + \underline{\ }\ H_2O \longrightarrow \underline{\ }\ H_3AsO_3 + \underline{\mathbf{?}}\ H^+ + \underline{\ }\ e^-$$

When this half-reaction equation is balanced, the coefficient for H^+ is

A. 2
B. 3
C. 6
D. 9

42. When a strip of zinc is placed in a $1.0\,M$ copper(II) chloride solution,

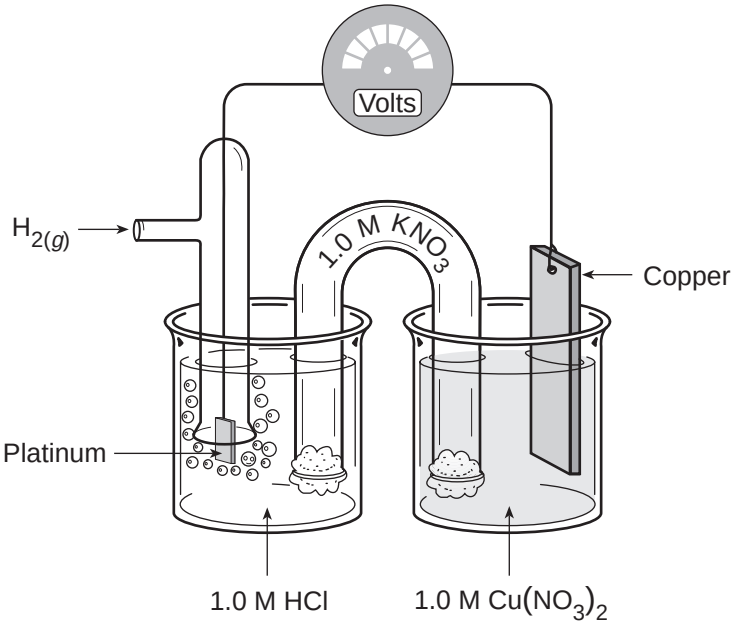
A. no change occurs.

B. the $\left[Cl^-\right]$ increases.

C. the $\left[Cu^{2+}\right]$ increases.

D. the $\left[Zn^{2+}\right]$ increases.

43. Consider the following electrochemical cell:



What changes occur when the cell is in operation?

	ANODE HALF-CELL	CATHODE HALF-CELL
A.	$[H_3O^+]$ increases	electrode increases in mass
B.	$[H_3O^+]$ increases	electrode decreases in mass
C.	$[H_3O^+]$ decreases	electrode increases in mass
D.	$[H_3O^+]$ decreases	electrode decreases in mass

OVER

44. A redox titration is performed in order to determine the $[H_2O_2]$.
Which of the following would **not** be a suitable reagent to use?

A. acidified IO_3^-
B. acidified SO_4^{2-}
C. acidified MnO_4^-
D. acidified $Cr_2O_7^{2-}$

45. Ethanol, C_2H_5OH, is oxidized by an acidified dichromate solution according to the following equation:

$$2Cr_2O_7^{2-} + 16H^+ + 3C_2H_5OH \rightarrow 4Cr^{3+} + 11H_2O + 3CH_3COOH$$

The $E°$ for the reaction above is $2.98\,V$. The $E°$ for the oxidation of ethanol is

A. $0.52\,V$
B. $1.23\,V$
C. $1.75\,V$
D. $2.98\,V$

46. Which of the following must be present to produce rust by the corrosion of iron?

I.	water
II.	oxygen
III.	salt

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

47. Why can an object **not** be plated with magnesium using $1.0\,M\ MgI_2$?

A. Water is a stronger reducing agent than I^-
B. Water is a stronger oxidizing agent than I^-
C. Water is a stronger reducing agent than Mg^{2+}
D. Water is a stronger oxidizing agent than Mg^{2+}

48. In the electrolysis of $1.0\,M\ Na_2SO_4$, what is formed at the cathode?

A. O_2
B. H_2
C. H_2SO_3
D. $S_2O_8^{2-}$

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

OVER

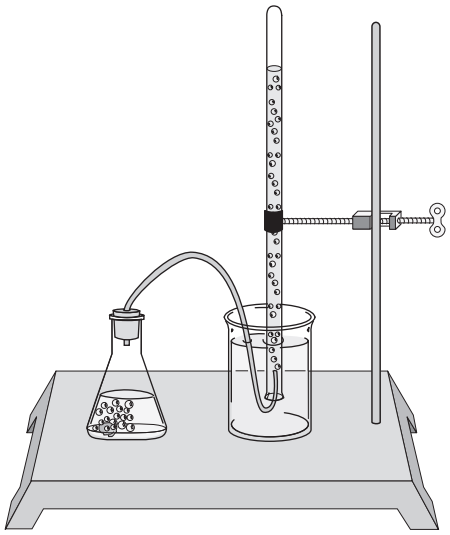
PART B: WRITTEN RESPONSE

Value: 32 marks **Suggested Time: 50 minutes**

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

1. An experiment is performed by displacement of water to determine the rate of the following reaction:

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



The following data is collected:

Time (s)	Volume of H_2 (mL)
0.0	0.0
10.0	21.1
20.0	40.9
30.0	60.0
40.0	77.6

a) Calculate the average rate of formation of H_2 in mL/s for the time interval between 20 and 40 seconds. **(2 marks)**

b) How does the rate of this reaction change as the reaction proceeds? Explain why. **(2 marks)**

2. Describe how enthalpy and entropy change, in the forward direction, as an exothermic reaction reaches equilibrium. Explain your reasoning. **(2 marks)**

Enthalpy: _____

Entropy: _____

Explanation: _____

_____

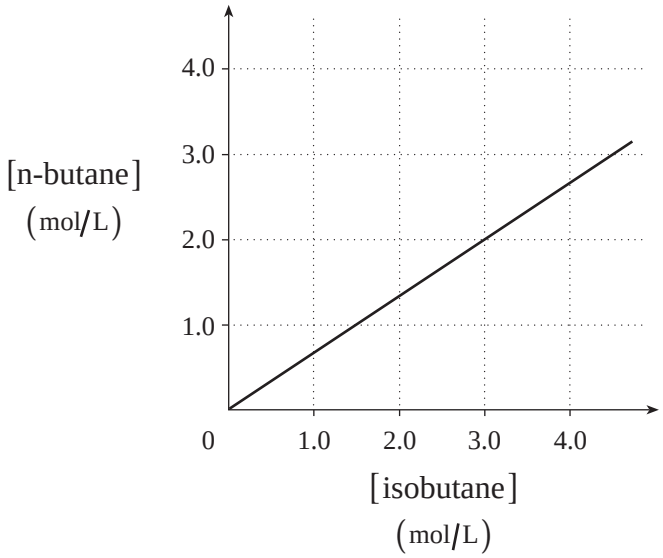
_____

3. Consider the graph below representing the following equilibrium:

$$CH_3CH_2CH_2CH_{3(g)} \rightleftarrows CH_3CH(CH_3)_{2(g)}$$

n-butane isobutane

Data for the graph was obtained from various equilibrium mixtures.



Calculate the value of K_{eq} for the equilibrium. **(2 marks)**

OVER

4. A $100.0\,\text{mL}$ sample of $0.600\,\text{M}\ \text{Ca}(\text{NO}_3)_2$ is diluted by adding $400.0\,\text{mL}$ of water. Calculate the concentration of ions in the resulting solution. **(2 marks)**

5. A maximum of $0.60\,\text{g}\ \text{Pb}(\text{NO}_3)_2$ can be added to $1.5\,\text{L}$ of $\text{NaBr}_{(aq)}$ without forming a precipitate. Calculate the $[\text{NaBr}]$. **(4 marks)**

6. Consider the following amphiprotic anions reacting with each other:

$$HC_6H_5O_7^{2-} + HC_2O_4^{-} \rightleftarrows \quad \textbf{?}$$

a) Complete the Brönsted-Lowry acid-base equilibrium for the predominant reaction. **(1 mark)**

b) Does the equilibrium above favour reactants or products? Explain. **(1 mark)**

OVER

7. Calculate the pH of a $1.5\,M$ H_2S solution. **(4 marks)**

8. Consider the following reaction:

$$2HCl_{(aq)} + Ba(OH)_{2(s)} \rightarrow BaCl_{2(aq)} + 2H_2O_{(\ell)}$$

When $3.16\,g$ samples of $Ba(OH)_2$ were titrated to the equivalence point with an HCl solution, the following data were recorded:

	Volume of HCl added
Trial 1	$37.80\,mL$
Trial 2	$35.49\,mL$
Trial 3	$35.51\,mL$

Using the data above, calculate the original $[HCl]$. **(4 marks)**

OVER

9. Balance the following redox reaction in acid:

$$N_2O_4 + In \rightarrow HNO_2 + In^{3+} \qquad (\text{acid}) \qquad \textbf{(3 marks)}$$

10. What is an *electrolytic cell*? **(2 marks)**

OVER

11. A solution contains either acidified IO_3^- or acidified SO_4^{2-}. Why could the solution be identified using $I^-_{(aq)}$? Provide equations to support your answer. **(3 marks)**

END OF EXAMINATION

INSERT STUDENT I.D. NUMBER (PEN)

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CHEMISTRY 12

April 1999

Course Code = CH

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CHEMISTRY 12

April 1999

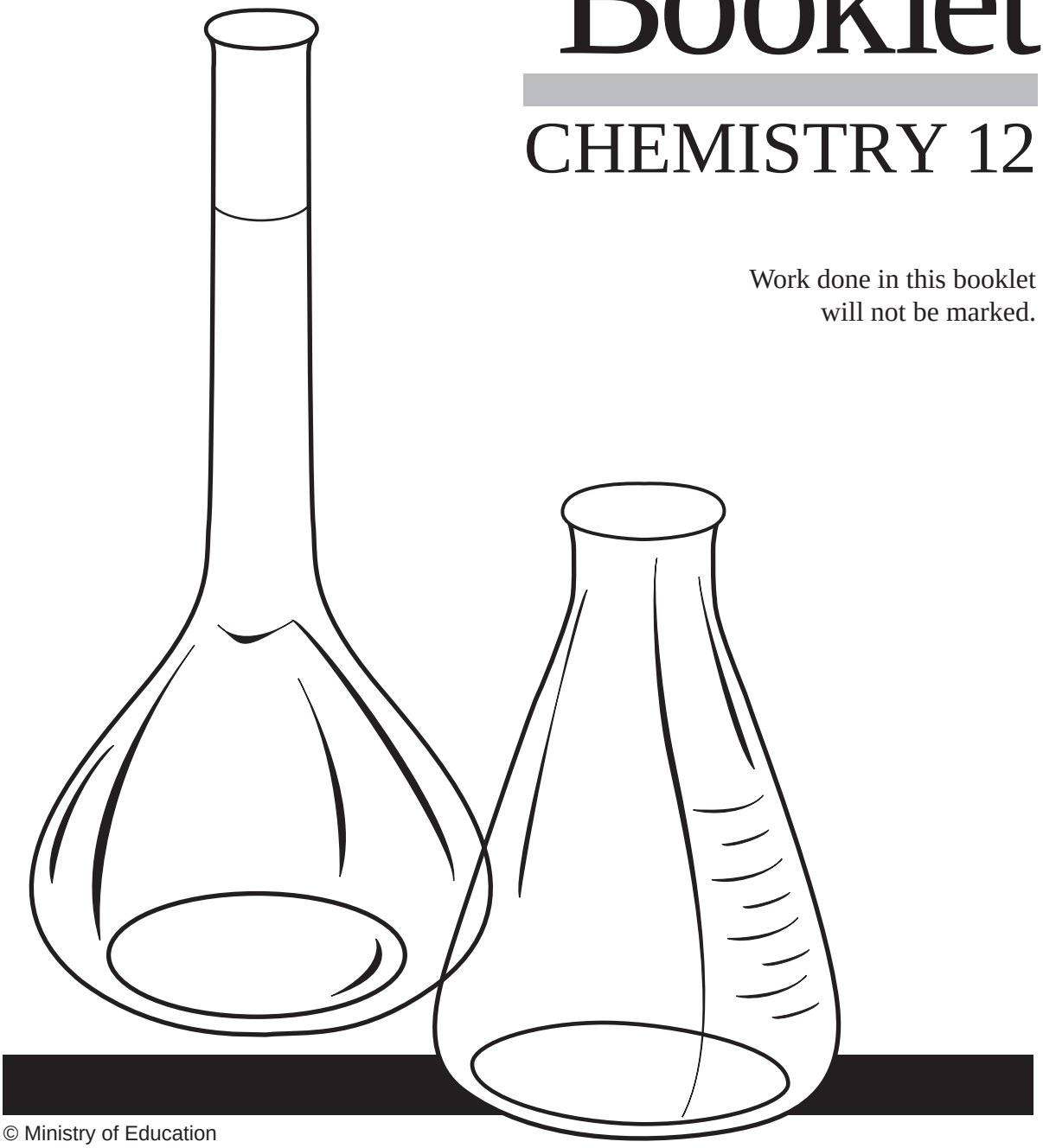
Course Code = CH

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

Data Booklet

CHEMISTRY 12

Work done in this booklet
will not be marked.



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Revised November 1994

CONTENTS

REFERENCE

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

PERIODIC TABLE OF THE ELEMENTS

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

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

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

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

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

ATOMIC MASSES OF THE ELEMENTS

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

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

NAMES, FORMULAE, AND CHARGES OF SOME COMMON IONS

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

* Aqueous solutions are readily oxidized by air.

** Not stable in aqueous solutions.

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

SOLUBILITY OF COMMON COMPOUNDS IN WATER

The term soluble here means > 0.1 mol/L at $25^{o}C$.

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

SOLUBILITY PRODUCT CONSTANTS AT 25˚C

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

RELATIVE STRENGTHS OF BRÖNSTED-LOWRY ACIDS AND BASES

in aqueous solution at room temperature

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

ACID-BASE INDICATORS

INDICATOR	pH RANGE IN WHICH COLOUR CHANGE OCCURS	COLOUR CHANGE AS pH INCREASES
Methyl violet	0.0 – 1.6	yellow to blue
Thymol blue	1.2 – 2.8	red to yellow
Orange IV	1.4 – 2.8	red to yellow
Methyl orange	3.2 – 4.4	red to yellow
Bromcresol green	3.8 – 5.4	yellow to blue
Methyl red	4.8 – 6.0	red to yellow
Chlorophenol red	5.2 – 6.8	yellow to red
Bromthymol blue	6.0 – 7.6	yellow to blue
Phenol red	6.6 – 8.0	yellow to red
Neutral red	6.8 – 8.0	red to amber
Thymol blue	8.0 – 9.6	yellow to blue
Phenolphthalein	8.2 – 10.0	colourless to pink
Thymolphthalein	9.4 – 10.6	colourless to blue
Alizarin yellow	10.1 – 12.0	yellow to red
Indigo carmine	11.4 – 13.0	blue to yellow

Standard Reduction Potentials of Half-Cells

Ionic Concentrations are at 1*M* in Water at 25° C

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

Overpotential Effect

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