INSERT STUDENT I.D. NUMBER (PEN)

STICKER IN THIS SPACE

JANUARY 1998

PROVINCIAL EXAMINATION

MINISTRY OF EDUCATION, SKILLS AND TRAINING

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:	10 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. 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 communication between calculators is prohibited during the examination. In addition to an approved calculator, students will be allowed to use rulers, compasses, and protractors during the examination.

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

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PART A: MULTIPLE CHOICE

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

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

1. Which of the following properties could be used to measure the rate of the following reaction taking place in an open container?

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

A. mass of Zn
B. solubility of HCl
C. concentration of Cl^-
D. colour of the solution

2. Consider the following reaction:

$$N_2 + 3H_2 \rightarrow 2NH_3$$

The rate of formation of NH_3 is 3.0 mL/min. The rate of consumption of H_2 is

A. 1.5 mL/min
B. 2.0 mL/min
C. 4.5 mL/min
D. 9.0 mL/min

3. Consider the following reaction mechanism:

Step 1: $NO_2 + NO_2 \rightarrow N_2O_4$

Step 2: $N_2O_4 + CO \rightarrow CO_2 + NO + NO_2$

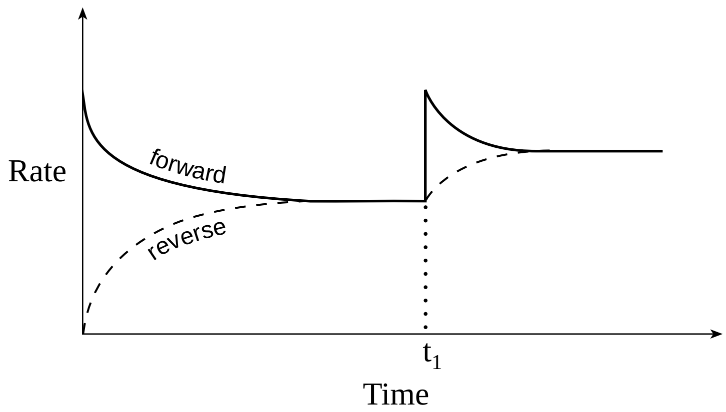
In the overall reaction, N_2O_4 is a

A. product.
B. catalyst.
C. reactant.
D. reaction intermediate.

OVER

4. Consider the rate diagram below for the following reaction:

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



Which of the following occurs at time t_1 ?

A. addition of H_2
B. addition of HI
C. addition of a catalyst
D. a decrease in volume

5. Chemical equilibrium is said to be dynamic because

A. the reaction proceeds quickly.
B. the mass of the reactants is decreasing.
C. the macroscopic properties are constant.
D. both forward and reverse reactions are occurring.

6. Which equation has the largest value of K_{eq} ?

A. $N_{2(g)} + O_{2(g)} \rightleftarrows 2NO_{(g)}$ $\Delta H = 21$ kJ
B. $C_2H_{6(g)} \rightleftarrows 2C_{(g)} + 3H_{2(g)}$ $\Delta H = 83$ kJ
C. $H_{2(g)} + \frac{1}{2}O_{2(g)} \rightleftarrows H_2O_{(g)}$ $\Delta H = -240$ kJ
D. $Ca_{(s)} + 2H_2O_{(\ell)} \rightleftarrows Ca(OH)_{2(aq)} + H_{2(g)}$ $\Delta H = -240$ kJ

7. Given the following system:

$$2CrO_4^{2-}{}_{(aq)} + 2H^+{}_{(aq)} \rightleftarrows Cr_2O_7^{2-}{}_{(aq)} + H_2O_{(\ell)}$$

Which of the following chemicals, when added to the above system at equilibrium, would result in a decrease in $[CrO_4^{2-}]$?

A. NaOH
B. HNO_3
C. Na_2CrO_4
D. $Na_2Cr_2O_7$

8. Addition of a catalyst to an equilibrium system

A. increases the value of K_{eq} .
B. increases the yield of products.
C. has no effect on the rates of reaction.
D. increases the rate of formation of both reactants and products.

9. Consider the following reaction:

$$2B_{(s)} + 3F_{2(g)} \rightleftarrows 2BF_{3(g)}$$

The equilibrium expression is

A. $K_{eq} = \frac{[2BF_3]}{[3F_2]}$

B. $K_{eq} = \frac{[F_2]^3}{[BF_3]^2}$

C. $K_{eq} = \frac{[BF_3]^2}{[F_2]^3}$

D. $K_{eq} = \frac{[BF_3]^2}{[B]^2[F_2]^3}$

OVER

10. The value of K_{eq} can be changed by

A. adding a catalyst.
B. changing the temperature.
C. changing the reactant concentration.
D. changing the volume of the container.

11. Consider the following equilibrium:

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

When 0.40 mol of PCl_3 and 0.40 mol of Cl_2 are placed in a 1.00 L container and allowed to reach equilibrium, 0.244 mol of PCl_5 are present. From this information, the value of K_{eq} is

A. 0.10
B. 0.30
C. 3.3
D. 10

12. Consider the following equilibrium:

$$PCl_{5(g)} \rightleftarrows PCl_{3(g)} + Cl_{2(g)} \qquad K_{eq} = 2.30$$

A 1.0 L container is filled with 0.05 mol PCl_5, 1.0 mol PCl_3, and 1.0 mol Cl_2.
The system proceeds to the

A. left because Trial $K_{eq} > K_{eq}$
B. left because Trial $K_{eq} < K_{eq}$
C. right because Trial $K_{eq} > K_{eq}$
D. right because Trial $K_{eq} < K_{eq}$

13. When solid AgBr is added to a saturated solution of AgBr, the reaction rates can be described as:

	RATE OF DISSOLVING	RATE OF CRYSTALLIZATION
A.	increases	increases
B.	increases	decreases
C.	decreases	increases
D.	increases	no change

14. Which of the following units can be used to represent solubility?

A. g
B. mol
C. mol/L
D. mL/s

15. When equal volumes of 0.2 M K_2CO_3 and 0.2 M Na_3PO_4 are mixed,

A. no precipitate will form.
B. a precipitate of K_3PO_4 will form.
C. a precipitate of Na_2CO_3 will form.
D. a precipitate of both K_3PO_4 and Na_2CO_3 will form.

16. A 3.0 L solution of $NiCl_2$ is found to have a chloride concentration of 0.60 M. The concentration of nickel(II) ions in this solution is

A. 0.30 M
B. 0.60 M
C. 0.90 M
D. 1.2 M

17. Which of the following causes a precipitate to form when $Sr^{2+}{}_{(aq)}$ is added but not when $Zn^{2+}{}_{(aq)}$ is added?

A. S^{2-}
B. Cl^{-}
C. $SO_4{}^{2-}$
D. $CO_3{}^{2-}$

18. The solubility of PbS is 2.9×10^{-14} M. What is the value of K_{sp} for PbS?

A. 8.4×10^{-28}
B. 2.9×10^{-14}
C. 5.8×10^{-14}
D. 1.7×10^{-7}

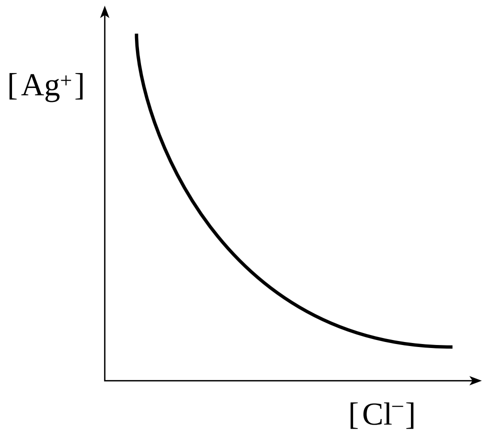
OVER

19. Consider the following equation:

$$AgCl_{(s)} \rightleftarrows Ag^{+}_{(aq)} + Cl^{-}_{(aq)}$$

Which of the following graphs represents the relationship between $[Ag^{+}]$ and $[Cl^{-}]$ in this system at a constant temperature?

A.



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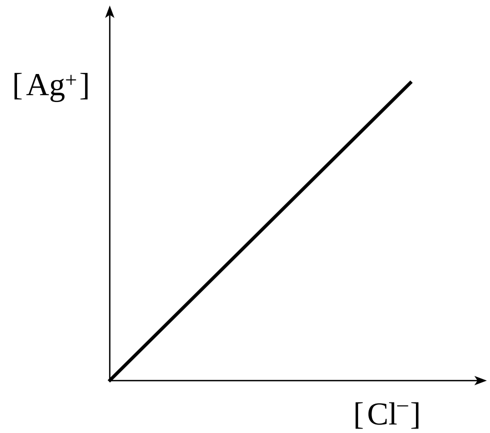
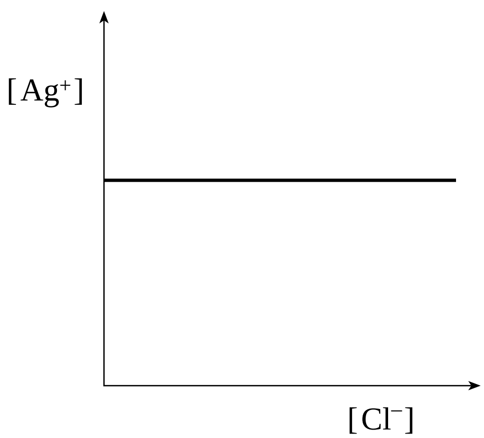
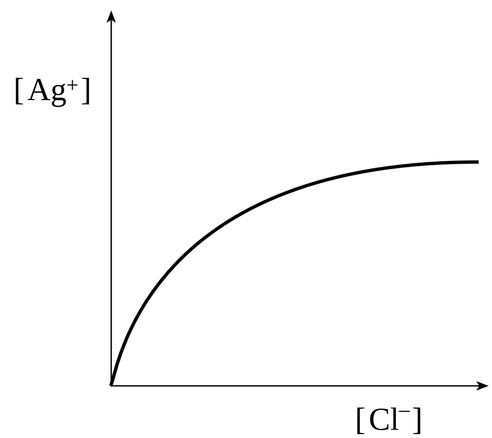


C.



D.



20. The acid found in vinegar will

A. taste bitter.
B. feel slippery.
C. change litmus to blue.
D. react with Mg to produce H_2

21. In which of the following equilibrium systems is HCO_3^- acting as a Brönsted-Lowry base?

A. $HCO_3^- \rightleftarrows H^+ + CO_3^{2-}$
B. $HCO_3^- + HS^- \rightleftarrows H_2S + CO_3^{2-}$
C. $HCO_3^- + H_2S \rightleftarrows H_2CO_3 + HS^-$
D. $HCO_3^- + H_2O \rightleftarrows H_3O^+ + CO_3^{2-}$

22. The conjugate acid of H_2O is

A. O^{2-}
B. OH^-
C. H_3O^+
D. H_2O_2

23. The strongest acid that can exist in an aqueous solution is

A. NH_2^-
B. H_3O^+
C. HNO_2
D. $HClO_4$

24. Which of the following is possible for an acid?

	ACID STRENGTH	CONCENTRATION	pH
A.	strong	0.01 M	2.0
B.	weak	0.01 M	1.0
C.	strong	3 M	5.5
D.	weak	3 M	–0.5

OVER

25. Consider the following equilibrium:

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

A small amount of HCl is added to water and equilibrium is reestablished. When comparing the new equilibrium with the original equilibrium,

A. $\left[H_3O^+\right]$ and pH both decreased.
B. $\left[H_3O^+\right]$ and pH both increased.
C. $\left[H_3O^+\right]$ increased and pH decreased.
D. $\left[H_3O^+\right]$ decreased and pH increased.

26. The $\left[H_3O^+\right]$ in 100.0 mL of 0.015 M KOH is

A. 6.7×10^{-13}
B. 6.7×10^{-12}
C. 1.5×10^{-3}
D. 1.5×10^{-2}

27. At any temperature, pK_w is defined as

A. $pK_w = pH + pOH$
B. $pK_w = pH - pOH$
C. $pK_w = pH \times pOH$
D. $pK_w = \frac{pH}{pOH}$

28. The $\left[OH^-\right]$ of a solution with pH 5.75 is

A. 5.6×10^{-9} M
B. 1.8×10^{-6} M
C. 7.6×10^{-1} M
D. 9.2×10^{-1} M

29. 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}

30. Which of the following 0.10 M solutions is basic?

A. LiCl
B. K_3PO_4
C. $NaClO_4$
D. NH_4NO_3

31. Consider the following equilibrium for the indicator HInd at its transition point:

$$HInd + H_2O \rightleftarrows Ind^- + H_3O^+$$

When a small amount of base is added, the equilibrium shifts to the

A. left and the $[HInd] > [Ind^-]$
B. left and the $[HInd] < [Ind^-]$
C. right and the $[HInd] > [Ind^-]$
D. right and the $[HInd] < [Ind^-]$

32. The approximate K_a value for the indicator thymolphthalein is

A. 1×10^{-10}
B. 1×10^{-4}
C. 4
D. 10

OVER

33. What volume of 0.100 M NaOH is needed to completely neutralize 25.0 mL of 0.100 M H_2SO_4?

A. 12.5 mL
B. 25.0 mL
C. 50.0 mL
D. 75.0 mL

34. When 0.10 mol of NaOH is added to 1.00 L of 0.30 M HCl, the pH of the resulting solution is

A. 0.52
B. 0.70
C. 1.00
D. 13.30

35. Which of the following could be used to form a buffer solution?

A. HBr and NaOH
B. HCl and NH_4Cl
C. HNO_3 and $NaNO_3$
D. H_2CO_3 and $NaHCO_3$

36. Normal rain has a pH of approximately 6 as a result of dissolved

A. oxygen.
B. carbon dioxide.
C. sulphur dioxide.
D. nitrogen dioxide.

37. Which of the following represents a redox reaction?

A. $H_2CO_3 \rightarrow H_2O + CO_2$
B. $CuS + H_2 \rightarrow H_2S + Cu$
C. $AgNO_3 + NaCl \rightarrow AgCl + NaNO_3$
D. $2HCl + Na_2SO_3 \rightarrow 2NaCl + H_2O + SO_2$

38. The oxidation number of carbon in $C_2O_4^{2-}$ is

A. +3
B. +4
C. +5
D. +6

39. Consider the following redox reaction:

$$3As_2O_3 + 4NO_3^- + 7H_2O + 4H^+ \rightarrow 6H_3AsO_4 + 4NO$$

The oxidizing agent is

A. H^+
B. H_2O
C. NO_3^-
D. As_2O_3

40. When W_2O_5 is converted to WO_2 in a redox reaction, the W has been

A. reduced since its oxidation number has increased.
B. reduced since its oxidation number has decreased.
C. oxidized since its oxidation number has increased.
D. oxidized since its oxidation number has decreased.

41. A student investigating redox reactions recorded the following results:

$$V^{2+} + Te^{2-} \rightarrow \text{no reaction}$$

$$U^{4+} + Te^{2-} \rightarrow U^{3+} + Te$$

Based on these results, the strengths of the oxidizing agents, arranged from strongest to weakest, are

A. V^{2+}, Te, U^{4+}
B. U^{4+}, Te, V^{2+}
C. U^{3+}, Te^{2-}, V^{2+}
D. V^{2+}, Te^{2-}, U^{3+}

42. A spontaneous redox reaction occurs when Sn^{2+} is mixed with

A. I_2
B. Cu
C. H_2S
D. Ag_2S

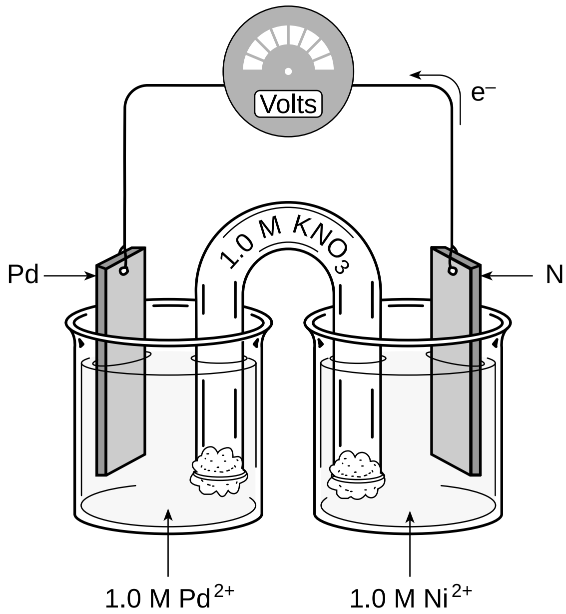
43. Consider the redox reaction below:

$$2BrO_3^- + 10Cl^- + 12H^+ \rightarrow Br_2 + 5Cl_2 + 6H_2O$$

The oxidation half-reaction involved in this reaction is

A. $2Cl^- \rightarrow Cl_2 + 2e^-$
B. $2H^+ \rightarrow H_2 + 2e^-$
C. $BrO_3^- + 6H^+ + 5e^- \rightarrow \frac{1}{2}Br_2 + 3H_2O$
D. $BrO_3^- + 6H^+ \rightarrow \frac{1}{2}Br_2 + 3H_2O + 5e^-$

Use the following diagram to answer questions 44, 45 and 46.



44. As the cell operates, the electrons flow from the nickel electrode to the palladium electrode. The reaction occurring at the anode is

A. $Pd \rightarrow Pd^{2+} + 2e^-$
B. $Ni \rightarrow Ni^{2+} + 2e^-$
C. $Pd^{2+} + 2e^- \rightarrow Pd$
D. $Ni^{2+} + 2e^- \rightarrow Ni$

45. As the cell operates,

A. both the K^+ and the NO_3^- migrate into the nickel half-cell.
B. both the K^+ and the NO_3^- migrate into the palladium half-cell.
C. the K^+ migrates into the nickel half-cell and the NO_3^- migrates into the palladium half-cell.
D. the K^+ migrates into the palladium half-cell and the NO_3^- migrates into the nickel half-cell.

46. The initial cell voltage is 1.21 V. The reduction potential of Pd^{2+} is

A. -1.21 V
B. -0.95 V
C. $+0.95$ V
D. $+1.21$ V

OVER

47. Consider the following chemicals:

I	water
II	oxygen gas
III	nitrogen gas

At $25°C$, a piece of iron rusts in the presence of

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

48. During the electrolysis of 1.0 M Na_2SO_4, the reaction at the cathode is

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

B. $2SO_4^{2-} \rightarrow S_2O_8^{2-} + 2e^-$

C. $2H_2O \rightarrow O_2 + 4H^+ + 4e^-$

D. $2H_2O + 2e^- \rightarrow H_2 + 2OH^-$

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

PART B: WRITTEN RESPONSE

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

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

1. Consider the following overall reaction:

$$2NO + 2H_2 \rightarrow 2H_2O + N_2$$

a) Explain why the reaction is likely to involve more than one step. **(1 mark)**

___

___

b) A proposed mechanism for the reaction is:

Step 1: $NO + H_2 \rightarrow N + H_2O$
Step 2: ?
Step 3: $N_2O + H_2 \rightarrow N_2 + H_2O$

i) Write the equation for Step 2. **(2 marks)**

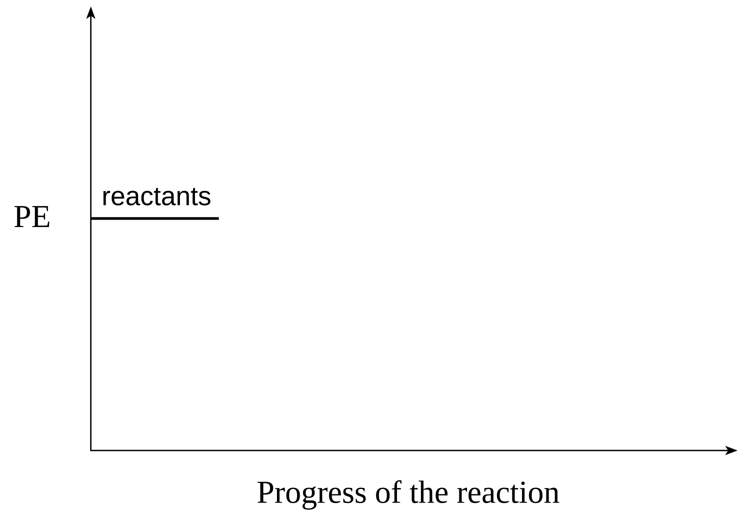
ii) Identify all reaction intermediates. **(1 mark)**

OVER

2. Consider the following equilibrium:

$$CS_{2(g)} + 3Cl_{2(g)} \rightleftarrows CCl_{4(g)} + S_2Cl_{2(g)} \qquad \Delta H = -238\text{ kJ}$$

a) Sketch a potential energy diagram for the reaction above and label ΔH. **(2 marks)**



b) Some CS_2 is added and equilibrium is then reestablished. State the direction of the equilibrium shift and the resulting change in $[Cl_2]$. **(1 mark)**

c) The temperature is decreased and equilibrium is then reestablished. What will the effect be on the value of K_{eq}? **(1 mark)**

3. A 100.00 mL sample of a saturated solution of $Ca(OH)_2$ is evaporated to dryness. The mass of the solid residue is 0.125 g. Calculate the solubility product of $Ca(OH)_2$.

(4 marks)

OVER

4. Write the net ionic equation representing the reaction that occurs when equal volumes of 0.20 M H_2SO_4 and 0.20 M $Ba(NO_3)_2$ are mixed together. **(2 marks)**

5. Define the term *strong Brönsted-Lowry acid*. **(2 marks)**

6. Nicotinic acid, $HC_6H_4NO_2$, is a weak acid found in vitamin B.
Calculate the pH of 0.010 M $HC_6H_4NO_2$ $\left(K_a = 1.4 \times 10^{-5}\right)$. **(4 marks)**

7. A solution of NaOH is used to neutralize separate solutions of HF and HBr.

a) Write the formula equation for the neutralization of HF. **(1 mark)**

b) Write the net ionic equation for the neutralization of HBr. **(1 mark)**

c) One of the neutralization reactions above produces a salt that undergoes hydrolysis.
Identify the salt and write the net ionic equation for the hydrolysis reaction. **(2 marks)**

OVER

8. Balance the following redox reaction: **(3 marks)**

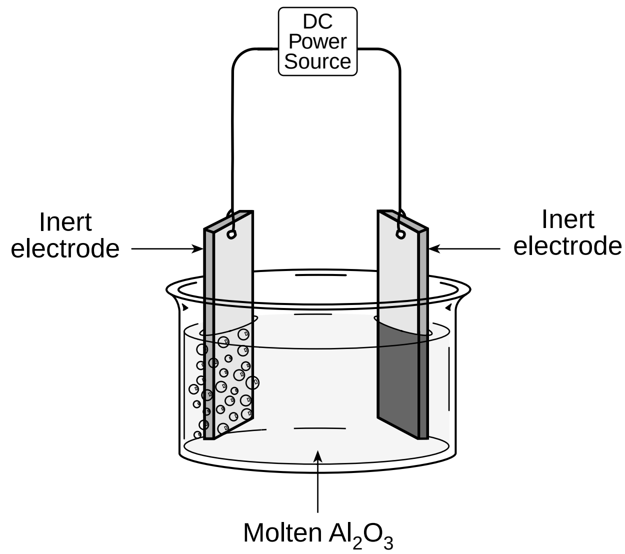
$$Sb + HSO_4^- \rightarrow Sb_2O_3 + SO_2 \qquad (\text{acid})$$

9. Consider the following redox reaction:

$$H_2Se + SO_4^{2-} + 2H^+ \rightarrow Se + H_2SO_3 + H_2O$$

Calculate the $E°$ for the reaction above. **(2 marks)**

10. Consider the following electrolytic cell used for the electrolysis of molten aluminum oxide.



a) Write the equation for the half-reaction taking place at the anode. **(1 mark)**

b) Write the equation for the half-reaction taking place at the cathode. **(1 mark)**

c) Clearly indicate on the diagram above, the direction of electron flow. **(1 mark)**

END OF EXAMINATION

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CHEMISTRY 12

January 1998

Course Code = CH

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CHEMISTRY 12

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Course Code = CH

Score for Question 1:	Score for Question 8:
1. ______ (4)	8. ______ (3)

Score for Question 2:	Score for Question 9:
2. ______ (4)	9. ______ (2)

Score for Question 3:	Score for Question 10:
3. ______ (4)	10. ______ (3)

Score for Question 4:

4. ______ (2)

Score for Question 5:

5. ______ (2)

Score for Question 6:

6. ______ (4)

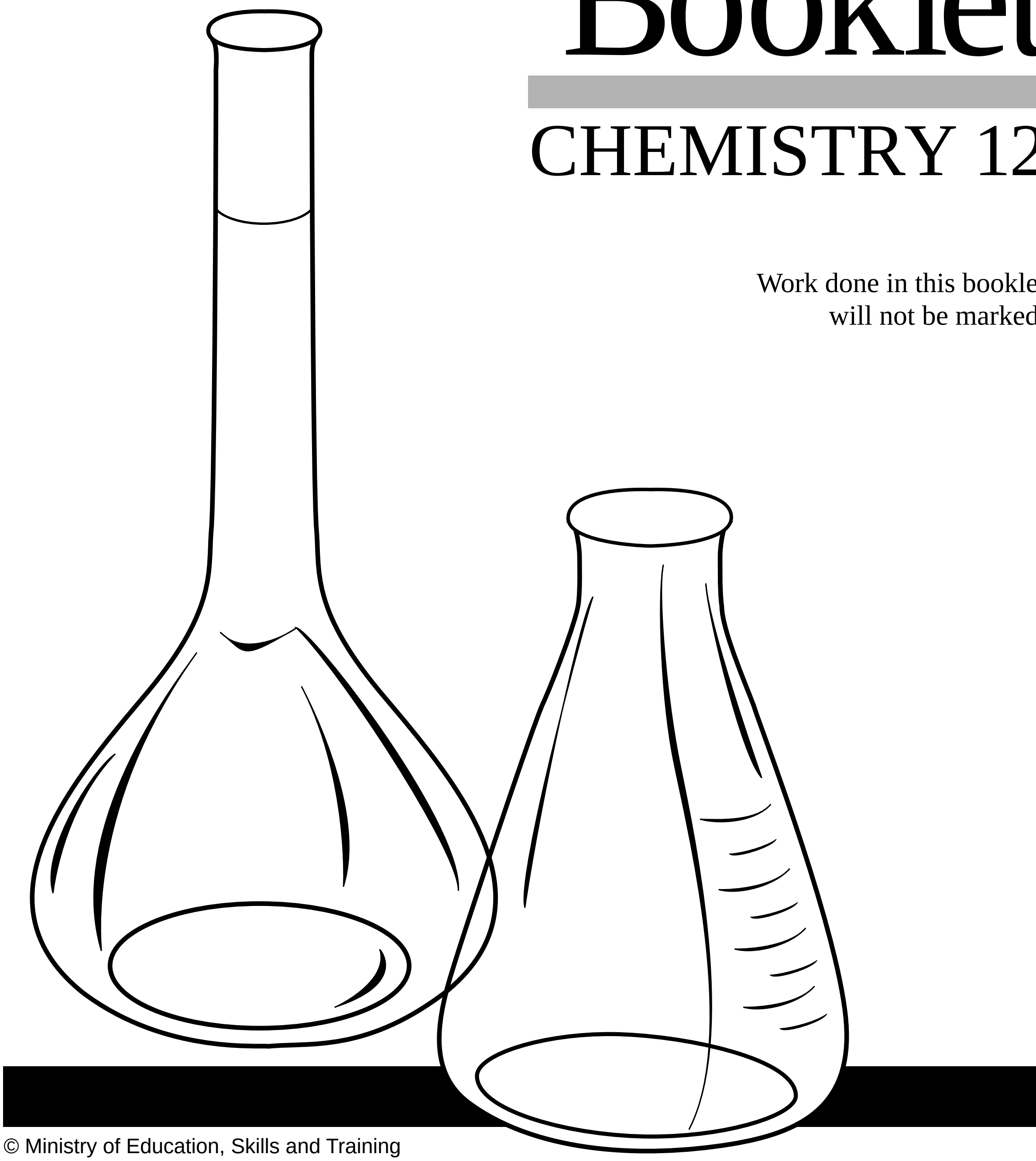
Score for Question 7:

7. ______ (4)

Data Booklet

CHEMISTRY 12

Work done in this booklet
will not be marked.



Revised November 1994

CONTENTS

REFERENCE

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

PERIODIC TABLE OF THE ELEMENTS

Key:

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

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 Ha Hahnium (262)	106 Sg Seaborgium (263)	107 Uns Unnilseptium (262)	108 Uno Unniloctium (265)	109 Une Unnilennium (266)									

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

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 > $0.1\ \text{mol/L}$ 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 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^+	$\rightleftharpoons$	$H^+ + H_2O$	1.0	
	Iodic	HIO_3	$\rightleftharpoons$	$H^+ + IO_3^-$	1.7×10^{-1}	
	Oxalic	$H_2C_2O_4$	$\rightleftharpoons$	$H^+ + HC_2O_4^-$	5.9×10^{-2}	
	Sulphurous $(SO_2 + H_2O)$	H_2SO_3	$\rightleftharpoons$	$H^+ + HSO_3^-$	1.5×10^{-2}	
	Hydrogen sulphate ion	HSO_4^-	$\rightleftharpoons$	$H^+ + SO_4^{2-}$	1.2×10^{-2}	
	Phosphoric	H_3PO_4	$\rightleftharpoons$	$H^+ + H_2PO_4^-$	7.5×10^{-3}	
	Hexaaquoiron ion, iron(III) ion	$Fe(H_2O)_6^{3+}$	$\rightleftharpoons$	$H^+ + Fe(H_2O)_5(OH)^{2+}$	6.0×10^{-3}	
	Citric	$H_3C_6H_5O_7$	$\rightleftharpoons$	$H^+ + H_2C_6H_5O_7^-$	7.1×10^{-4}	
	Nitrous	HNO_2	$\rightleftharpoons$	$H^+ + NO_2^-$	4.6×10^{-4}	
	Hydrofluoric	HF	$\rightleftharpoons$	$H^+ + F^-$	3.5×10^{-4}	
	Methanoic, formic	$HCOOH$	$\rightleftharpoons$	$H^+ + HCOO^-$	1.8×10^{-4}	
	Hexaaquochromium ion, chromium(III) ion	$Cr(H_2O)_6^{3+}$	$\rightleftharpoons$	$H^+ + Cr(H_2O)_5(OH)^{2+}$	1.5×10^{-4}	
	Benzoic	C_6H_5COOH	$\rightleftharpoons$	$H^+ + C_6H_5COO^-$	6.5×10^{-5}	
	Hydrogen oxalate ion	$HC_2O_4^-$	$\rightleftharpoons$	$H^+ + C_2O_4^{2-}$	6.4×10^{-5}	
	Ethanoic, acetic	CH_3COOH	$\rightleftharpoons$	$H^+ + CH_3COO^-$	1.8×10^{-5}	
	Dihydrogen citrate ion	$H_2C_6H_5O_7^-$	$\rightleftharpoons$	$H^+ + HC_6H_5O_7^{2-}$	1.7×10^{-5}	
	Hexaaquoaluminum ion, aluminum ion	$Al(H_2O)_6^{3+}$	$\rightleftharpoons$	$H^+ + Al(H_2O)_5(OH)^{2+}$	1.4×10^{-5}	
	Carbonic $(CO_2 + H_2O)$	H_2CO_3	$\rightleftharpoons$	$H^+ + HCO_3^-$	4.3×10^{-7}	
	Monohydrogen citrate ion	$HC_6H_5O_7^{2-}$	$\rightleftharpoons$	$H^+ + C_6H_5O_7^{3-}$	4.1×10^{-7}	
	Hydrogen sulphite ion	HSO_3^-	$\rightleftharpoons$	$H^+ + SO_3^{2-}$	1.0×10^{-7}	
	Hydrogen sulphide	H_2S	$\rightleftharpoons$	$H^+ + HS^-$	9.1×10^{-8}	
	Dihydrogen phosphate ion	$H_2PO_4^-$	$\rightleftharpoons$	$H^+ + HPO_4^{2-}$	6.2×10^{-8}	
	Boric	H_3BO_3	$\rightleftharpoons$	$H^+ + H_2BO_3^-$	7.3×10^{-10}	
	Ammonium ion	NH_4^+	$\rightleftharpoons$	$H^+ + NH_3$	5.6×10^{-10}	
	Hydrocyanic	HCN	$\rightleftharpoons$	$H^+ + CN^-$	4.9×10^{-10}	
	Phenol	C_6H_5OH	$\rightleftharpoons$	$H^+ + C_6H_5O^-$	1.3×10^{-10}	
	Hydrogen carbonate ion	HCO_3^-	$\rightleftharpoons$	$H^+ + CO_3^{2-}$	5.6×10^{-11}	
	Hydrogen peroxide	H_2O_2	$\rightleftharpoons$	$H^+ + HO_2^-$	2.4×10^{-12}	
	Monohydrogen phosphate ion	HPO_4^{2-}	$\rightleftharpoons$	$H^+ + PO_4^{3-}$	2.2×10^{-13}	
	Water	H_2O	$\rightleftharpoons$	$H^+ + OH^-$	1.0×10^{-14}	
	Hydroxide ion	OH^-	$\leftarrow$	$H^+ + O^{2-}$	very small	
Weak	Ammonia	NH_3	$\leftarrow$	$H^+ + NH_2^-$	very small	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