Acids & Bases – 2 - Revision Problems

Titrations

1.   Anhydrous sodium carbonate is a common basic primary standard.

   a) Why is this substance chosen as a primary standard instead of the more familiar sodium hydroxide?

   b) What must be done to a sample of sodium carbonate before it can be used as a primary standard?

2.   Potassium hydrogen phthalate ($KHC_8H_4O_4$) is often used as a primary standard in the standardisation of basic solutions. What properties must be possessed by this substance?

3.   A student wants to prepare exactly 1.00 L of 0.0500 mol L^{-1} hydrochloric acid from an accurately known 1.063 mol L^{-1} stock solution.

   a) What volume of this stock solution is needed?

   b) What piece of apparatus should be used to measure out this volume, and in what piece of apparatus should the exact 1.00 L of solution be prepared?

   c) Describe the procedure, in point form, that should be followed to make up the dilute solution.

4.   Why is it acceptable for a volumetric flask to contain a little distilled water, left over from washing, before it is used to make up a standard solution?

5.   Why must a pipette be rinsed with the solution that is about to be pipetted, rather than being rinsed with distilled water?

6   Why, before being filled, must a burette be first rinsed with the solution that is to be delivered from it, rather than being rinsed with water.

7   In a titration, why can the conical flask, into which the aliquot is about to be pipetted, still contain a few drops of distilled water left over from the rinsing process i.e. why does it not need to be dry?

8   Why can't sodium hydroxide be used as a primary standard?

9   Why can't hydrated sodium carbonate, $Na_2CO_3.10H_2O$, be used as a primary standard?

10   A student wishes to make up 500 mL of 0.100 mol L^{-1} sodium carbonate solution.

   a) What mass of anhydrous sodium carbonate is required for the solution?

   b) The steps undertaken to make up this solution are listed below. What is the correct order in which you should follow these steps?

      A   The 500 mL of solution is thoroughly shaken in the volumetric flask

      B   The solid sodium carbonate is transferred to the volumetric flask

      C   The volumetric flask and contents are swirled until the sodium carbonate is dissolved

      D   The volumetric flask is washed with distilled water

      E   About 250 mL of distilled water is added to the volumetric flask

      F   The required mass of sodium carbonate is weighed out in a beaker

      G   The beaker is washed out, to ensure complete transfer of the solid, and the washings added to the volumetric flask

      H   Distilled water is added to the volumetric flask to make the solution up to the calibrated mark.

11.   Consider a titration of sodium hydroxide solution with hydrochloric acid solution, with the hydrochloric acid in the burette. What steps should be taken with the pipette and burette before use?

12.   Outline, in point form, the experimental steps you would undertake to measure to concentration of a solution of acetic acid, using a standard solution of sodium hydroxide.

13. A solution of pure sodium carbonate is to be titrated with standard hydrochloric acid and 25.00 mL of the carbonate solution is pipetted into a conical flask. Which one, or more, of the following procedures is INCORRECT?

   a) The conical flask is washed with sodium carbonate solution immediately before the pipetting.

   b) The conical flask is washed with distilled water immediately before the pipetting.

   c) The pipette is rinsed with sodium carbonate solution immediately before use.

   d) The pipette is rinsed with water immediately before the carbonate solution is pipetted

   e) The burette is rinsed with some of the standard hydrochloric acid immediately before use.

Titrations & indicators

14. A sample of sodium carbonate, believed to be the pure decahydrate, was weighed and dissolved in water. The method of analysis required the addition of three drops of methyl orange indicator and titration of the solution against a previously standardised hydrochloric acid which had a concentration of 0.106 mole L^{-1}.

   The mass of sample taken was such that, on the assumption that the solid had the formula $Na_2CO_3.10H_2O$, an equivalence point would be expected for the titration after the addition of 15.36 mL of acid. Instead, the end-point occurred after the addition of 24.88 mL. We could conclude then that:

   a) the pipetted used was wet with water.
   b) six drops of methyl orange were used instead of three drops as directed.
   c) the original carbonate sample was extensively dehydrated (i.e. had lost some of the water of crystallisation)
   d) the standardised acid was in fact more concentrated than the molarity quoted.
   e) phenolphthalein should have been used as the indicator instead of methyl orange.

   Which conclusion is correct?

15. Examine the following table of indicators.

Indicator	Colour		pH range of colour change
	Acid	Base	
Congo red	Blue	Red	3.0 - 5.0
Methyl orange	Red	Yellow	3.2 - 4.4
Bromocresol green	Yellow	Blue	3.8 - 5.4
Methyl red	Red	Yellow	4.8 - 6.0
Bromothymol blue	Yellow	Blue	6.0 - 7.6
Phenol red	Yellow	Red	6.6 - 8.0
Phenolphthalein	Colourless	Pink	8.2 - 10.0
Alizarin yellow	Yellow	Red	10.1 - 12.0

   Select an appropriate indicator for use in each of the following titrations

   a) sodium hydroxide with hydrochloric acid   b) potassium hydroxide with nitric acid

   c) sodium hydroxide with acetic acid   d) ammonia with hydrochloric acid

16. The concentration of a solution of a weak acid HClO, is determined by titrating 10.0 mL of the HClO solution with 0.0500 mol L^{-1} solution of potassium hydroxide. The change in the pH as potassium hydroxide solution is added to the acid is shown in the graph.
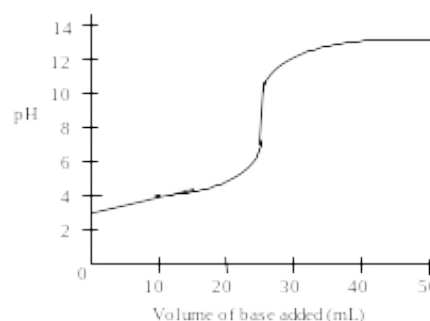
   For all parts of this question, refer to the titration curve on the right.

   a) i) Write a balanced ionic equation to represent the reaction between potassium hydroxide and the weak acid HClO.

   ii) Calculate the concentration of the acid HClO.

   iii) What is the pH of this solution of HClO (i.e. prior to the commencement of the titration)?

   iv) Give a reason why HClO may be regarded as a weak acid.

   v) Write the expression for the acid dissociation constant, K_a, for HClO.

   b) i) What is the approximate pH of the equivalence point for this titration?

   ii) Use relevant ionic equations to explain why this particular equivalence pH is obtained.

16. (cont)

c) From the table below, select the most suitable indicator to detect the equivalence point of the titration.   Give a reason for your choice.

Indicator	pH range	Colour change
Alizarin yellow	10.0 - 12.0	yellow to orange-red
Thymol blue	8.0 - 9.6	yellow to blue
Azolitmin	5.0 - 8.0	red to blue

17. A chemist is attempting to establish the concentration of a nitric acid solution using a standard solution   made from anhydrous sodium carbonate, Na_2CO_3. Indicate which of the following would <u>increase,</u> <u>decrease</u> or have <u>no effect</u> on the estimation of the concentration of the nitric acid. Explain your answers.

a) The burette is rinsed with distilled water, but not dried, prior to the addition of the nitric acid.

b) The pipette is rinsed with water only, prior to taking an aliquot of sodium carbonate solution.

c) The flask into which the aliquot of sodium carbonate is added is rinsed with water, but not dried, prior to the addition.

d) The sodium carbonate is contaminated with sodium hydrogencarbonate, $NaHCO_3$.

Sulfuric acid, hydrochloric acid, sodium hydroxide and ammonia

18. This question concerns the chemistry of sulfuric acid.

a) Give the name and chemical formula of a naturally occurring mineral substance which can be used as a starting point for the manufacture of sulfuric acid.

b) Write a balanced equation for the production of SO_2 from the substance you have named in part a).

c) Describe how the industrial oxidation of SO_2 to SO_3 is accomplished.

d) Suggest a reason for using an excess of air in the process described in c)

e) Why must the gases be thoroughly purified prior to the process described in c)

f) Write an equation for the conversion of sulfur dioxide to sulfur trioxide

g) Is the reaction in f) exothermic or endothermic?

h) Using only the concepts of equilibrium, what conditions of temperature and pressure would favour the formation of sulfur trioxide? Justify your choice.

i) In what way, and why, do the conditions used in the manufacture of sulfuric acid differ from those described in h)?

j) Why is the gas mixture cooled as it passes from one catalyst bed to the next?

k) Write a balanced equation for the reaction between SO_3 and water to give sulfuric acid

l) How is the final step i.e. reaction k), carried out in the industrial process?

m) Give two uses of sulfuric acid. Briefly describe the chemistry involved in these uses.

19. When a student added a solution of sodium hydroxide to each of the solutions listed below , she noted the following observations:

Solution	Observation
barium chloride	a colourless solution was obtained
magnesium chloride	a white precipitate was obtained
zinc chloride	a colourless solution was obtained

Explain these results, using equations to support your answer.

20. When several drops of 1 mol L^{-1} sodium hydroxide solution are added to 1 mol L^{-1} aluminium nitrate solution, a white precipitate is formed. However, when more of the sodium hydroxide solution is added, this precipitate dissolves and a colourless solution is obtained.   Explain these observations, using equations to support your answer.

21. a) When magnesium and zinc are each added to 2 mol L^{-1} hydrochloric acid , similar observations are obtained.

    i) What are these observations?

    ii) Write equations to explain these observations.

    b) When magnesium and zinc are each added to 2 mol L^{-1} sodium hydroxide solution, different observations are obtained.

    i) What are these observations?

    ii) Write equations to explain these observations.

22. Ammonia can be produced by reacting nitrogen with hydrogen: $N_2(g) + 3 H_2(g) \rightleftharpoons 2 NH_3(g)$
    At 25°C, the equilibrium constant for this reaction is 4×10^8.

    a) Considering the equilibrium constant, at room temperature, for this reaction is very large, what problem is faced by chemists in trying to manufacture ammonia by this method?

    b) How is this problem overcome?

    c) What use can be made of Le Chatelier's principle in determining the conditions used in the manufacture of ammonia?

    d) Nitrogen and hydrogen are moderately expensive chemicals and must not be wasted. What use is made of the properties of ammonia so that no hydrogen and nitrogen are wasted?

23. Give concise explanations for the following.

    a) Ammonia dissolves in water to give solution of pH greater than 7.

    b) When concentrated ammonia is added to $CuSO_4$ dissolved in water, initially a pale blue precipitate forms which eventually dissolves to give a deep blue solution.

    c) When concentrated ammonia is added to $Al(NO_3)_3$ dissolved in water, a white precipitate is formed and it does not dissolve.

24. An innovative gardener has at her disposal a supply of calcium phosphate, potassium hydroxide, sodium hydroxide, nitric acid, hydrochloric acid and universal indicator .

    a) Explain how she could use these chemicals (not necessarily all of them) to make up a suitable complete fertiliser (it can be a mixture of several different substances) giving the essential growth nutrients, phosphorus, nitrogen and potassium, in such a way as to avoid killing her plants.

    b) Describe, using chemical equations where appropriate, the important chemical reactions which would occur in the preparation of the fertiliser.

Acid/base ionic equations

25. Write equations (ionic where appropriate) for the following reactions.
    For the examples marked "observation", describe the expected observations such as colour changes, precipitate formation (give the colour) or gas evolution (give the colour or describe as colourless) resulting from the chemical reaction.

    a. ammonia gas with hydrogen chloride gas   (observation)

    b. zinc with hydrochloric acid solution   (observation)

    c. nitric acid solution with potassium hydroxide solution

    d. dilute hydrochloric acid with calcium carbonate   (observation)

    e. sulfuric acid solution with sodium sulfide solution   (observation)

    f. sulfuric acid solution with solid sodium sulfite   (observation)

    g. hydrochloric acid solution and aluminium oxide   (observation)

    h. hydrochloric acid solution with a solution of ammonia

    i. hydrogen gas with chlorine gas

    j. sulfur is burnt in air

25. (cont) k. sulfur dioxide with oxygen, in the presence of a catalyst

   l. sulfur trioxide with concentrated sulfuric acid

   m. a solution of ammonia with a solution of sulfuric acid

   n. magnesium with 0.1 mol L^{-1} sulfuric acid   (observation)

   o. magnesium with hot concentrated sulfuric acid   (observation)

   p. copper with 2 mol L^{-1} hydrochloric acid   (observation)

   q. copper with concentrated nitric acid   (observation)

   r. a solution of nitric acid with a solution of ammonia

   s. aqueous solutions of sodium hydroxide and nitric acid

   t. sulfur dioxide gas with a solution of sodium hydroxide

   u. carbon dioxide gas with a solution of sodium hydroxide

   v. aluminium hydroxide with a solution of sodium hydroxide   (observation)

   w. aluminium hydroxide with hydrochloric acid solution   (observation)

   x. a solution of aluminium nitrate with excess sodium hydroxide solution

   y. magnesium hydroxide with a solution of sodium hydroxide   (observation)

   z. magnesium hydroxide with hydrochloric acid solution   (observation)

   A. a solution of sodium hydroxide with a solution of magnesium nitrate   (observation)

   B. zinc hydroxide with a solution of sodium hydroxide   (observation)

   C. a solution of sodium hydroxide (in excess) with a solution of zinc nitrate

   D. chromium (III) hydroxide with a solution of sodium hydroxide

   E. a solution of chromium (III) chloride with excess sodium hydroxide solution

   F. copper hydroxide with a solution of sodium chloride   (observation)

   G. a solution of copper sulfate with a solution of sodium hydroxide   (observation)

   H. a solution of iron (III) chloride with a solution of sodium hydroxide   (observation)

   I. a solution of sodium hydroxide with a solution of potassium chloride

   J. a solution of sodium hydroxide with chromium   (observation)

   K. a solution of sodium hydroxide with zinc   (observation)

   L. a solution of sodium hydroxide with aluminium   (observation)

   M. aluminium oxide with a solution of sodium hydroxide   (observation)

   N. nitrogen gas with hydrogen gas in the presence of an iron catalyst

   O. ammonia gas with water

   P. a solution of ammonia with a solution of magnesium nitrate   (observation)

   Q. aqueous solutions of ammonia and iron(III) chloride   (observation)

   R. aqueous solutions of ammonia and aluminium nitrate   (observation)

   S. aqueous solution of ammonia and sodium chloride

   T. a solution of ammonia (in excess) with a solution of copper sulfate   (observation)

   U. a solution of ammonia (in excess) with a solution of zinc nitrate   (observation)

   V. a solution of ammonia (in excess) with solid copper hydroxide   (observation)

   W. a solution of ammonia with silver oxide   (observation)

   X. a solution of ammonia (in excess) with a solution of iron(II) nitrate   (observation)

Miscellaneous multiple-choice problems

26. A "primary standard " reagent for chemical analysis *must* be

    A a crystalline solid   B of high molar mass   C highly soluble in water
    D of definite composition and high purity   E efflorescent and not deliquescent.

27. The laboratory glassware used in volumetric analysis exercises should be washed and rinsed before use. In some cases the final rinse is done with distilled water. For which piece(s) of apparatus, is the use of water for a final rinse allowable?

    A volumetric flask and pipette   B pipette   C burette
    D conical flask   E burette and conical flask.

28. A student attempting to standardise a hydrochloric acid solution by titration of it against 20.00 mL aliquots of standardised sodium carbonate had difficulty in obtaining accurate results. Which one of the following steps could be responsible for this lack of accuracy?

    A The burette was cleaned and rinsed thoroughly with distilled water before being filled.
    B Several 250 mL conical flasks were washed and rinsed thoroughly with distilled water.
    C A clean pipette was rinsed with sodium carbonate solution and a 20.00 mL aliquot was carefully pipetted into each conical flask.
    D Approximately 20 mL of distilled water was added from a measuring cylinder to each flask followed by two drops of methyl orange indicator.
    E To each flask in turn, hydrochloric acid was added with care from the burette until the yellow to red colour change was observed, and the volume added was recorded.

29. Which of the following pairs of metal hydroxides will react with excess ammonia solution?

    A $Cu(OH)_2$ and $Zn(OH)_2$ B $Zn(OH)_2$ and $Al(OH)_3$ C $Al(OH)_3$ and $Cr(OH)_3$
    D $Fe(OH)_2$ and $Cu(OH)_2$ E $Fe(OH)_2$ and $Fe(OH)_3$

30. A student completed an experiment where he titrated HCl against limestone to determine the purity of the limestone. The burette used was cleaned by first rinsing with HCl and then finally rinsing with distilled water. This final rinse with distilled water:

    A will give greatest accuracy for the burette.
    B will decrease the titre volume and give a higher percentage purity for limestone.
    C will increase the titre volume and give a lower percentage purity for limestone.
    D will increase the titre volume and give a higher percentage purity for limestone.
    E will decrease the titre volume and give a lower percentage purity for limestone.

31. Vinegar is diluted 10 times (x 10), and a 20.0 mL sample of the diluted vinegar requires 15.0 mL of 0.102 mol L^{-1} NaOH to neutralise the acetic acid (CH_3COOH). The percentage of acetic acid in vinegar calculated from these figures would be (assuming vinegar density of 1 g cm^{-3}):

    A x x 100   B x   C x

    D x 10 x   E x

32. Which of the following is CORRECT?

    A All indicators change colour at pH = 7
    B The end point of an acid-base reaction is at pH = 7
    C At the equivalence point for a reaction between a strong acid and a weak base, the solution will have pH > 7
    D Phenolphthalein may be used as the indicator of choice in a titration of strong base with weak acid
    E The substance of unknown concentration must always be placed in the burette in a titration

33. What is the best indicator to use when titrating a solution of ammonia of concentration 0.1 mol L^{-1} with a solution of hydrochloric acid of the same concentration?

    A phenolphthalein   (pH range 8 to 10)   B phenol red   (pH range 7 to 9)
    C bromothymol blue   (pH range 6 to 8)   D methyl red   (pH range 4 to 6)

34. The graph below shows how the pH of a solution changes during a certain titration.
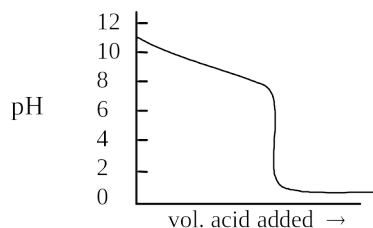
To which of the following titrations does the curve relate?

A strong base with strong acid

B strong base with weak acid

C weak base with strong acid

D weak base with weak acid

35. Consider the following five acid-base titrations:

    a) sodium carbonate vs hydrochloric acid
    b) sodium hydroxide vs acetic acid (acetic acid)
    c) sodium carbonate vs sulfuric acid
    d) ammonia vs hydrochloric acid
    e) barium hydroxide vs hydrofluoric acid

In which of these would phenolphthalein be the most appropriate indicator for the end-point determination of complete neutralisation of the base

A a) and c) only

B b) only

C c) and d) only

D b) and e) only

E a), c) and d) only

36. When either sodium hydroxide solution or ammonia solution are added to solutions of Ca^{2+}, Cu^{2+}, Zn^{2+}, and Fe^{2+} precipitates of the hydroxide are initially obtained in all cases. In which of the following cases, does addition of further base result in the precipitate dissolving?

A NaOH added to Cu^{2+}(aq)

B NH_3 added to Ca^{2+}(aq)

C NaOH added to Zn^{2+}(aq)

D NH_3 added to Fe^{2+}(aq)

37. Which of the following terms is matched with its correct meaning?

	Term	Meaning
A	deliquescent	gives off water when exposed to air
B	aliquot	the volume of liquid delivered from a burette to another liquid contained in a flask
C	equivalence point	the point in a titration when the indicator changes colour
D	primary standard	a substance which can be accurately weighed out and made up into a solution of known concentration

38. Which of the following would not be a suitable use for sulfuric acid?

A Cleaning of iron prior to galvanising

B As a fertiliser

C As a laboratory reagent

D As the electrolyte in a car battery.

39. When ammonia is passed through XSO_4 solution, a precipitate is formed first which gradually dissolves to give a solution. X is:

A Ca^{2+}

B Cu^{2+}

C Fe^{2+}

D Mg^{2+}

40. When a weak base and a strong acid are dissolved in water, they form a solution that is

A weakly basic

B neutral

C strongly basic

D weakly acidic

41. A student attempting to standardise a sodium hydroxide solution by titration of 20.00 mL aliquots against standard hydrochloric acid solution experienced difficulty in obtaining consistent values for the volume of titrant added. Which one of the following sequential steps could be responsible for this lack of precision?

A The burette was cleaned and rinsed thoroughly with the standard acid solution before being filled.

B Several 250 mL conical flasks were washed, and rinsed thoroughly with the sodium hydroxide solution.

C A clean pipette was rinsed with sodium hydroxide solution and a 20.00 mL aliquot was carefully pipetted into each conical flask.

D Approximately 20 mL of distilled water was added from a measuring cylinder to each flask followed by 2 drops of methyl orange indicator.

E To each flask in turn, standard hydrochloric acid solution was added with care from the burette until the yellow to red colour change was observed, and the volume added was recorded.

42. A solution of sodium hydroxide (solution 1.) is to be analysed by titration with standard hydrochloric acid. A 25.00 mL sample of solution 1. is pipetted into a conical flask, 25 mL of water and 2 drops of indicator added, and the solution titrated with 0.100 mol L⁻¹ hydrochloric acid (solution 2.) from a burette. The correct rinsing procedure is:

A Rinse the pipette and flask with solution 1. and the burette with distilled water.
B Rinse the pipette and flask with solution 1. and the burette with solution 2.
C Rinse the pipette with solution 1., the flask with distilled water and the burette with solution 2.
D Rinse the pipette, flask and burette with distilled water.
E Rinse the pipette with distilled water, the flask with solution 1. and the burette with solution 2.

43. A solution of sodium hydroxide in a conical flask is titrated with sulfuric acid solution from a burette. Which of the following alternatives correctly lists each of the rinsing agents required to rinse the conical flask, the pipette and the burette prior to commencing the titration?

	Conical Flask	Pipette	Burette
A	the NaOH solution	distilled water	the H_2SO_4 solution
B	the NaOH solution	the NaOH solution	the H_2SO_4 solution
C	distilled water	the NaOH solution	the H_2SO_4 solution
D	the NaOH solution	distilled water	distilled water

Miscellaneous short-answer problems

44. A student used the following procedure to prepare a standard hydrochloric acid solution with a concentration of approximately 0.1 mol L⁻¹.

   Step 1: Prepared a solution of hydrochloric acid with concentration approximately 0.1 mol L⁻¹.
   Step 2: Standardised the hydrochloric acid by titration against anhydrous sodium carbonate. The hydrochloric acid was in the burette and the sodium carbonate in a conical flask.

   Explain why the hydrochloric acid was standardised using sodium carbonate instead of sodium hydroxide.

45. Write a brief explanation for the following:
   Sodium carbonate is heated in an oven and cooled in a desiccator when used as a primary standard in volumetric analysis.

46. Write ionic equations for the reactions which occur in the following experiments. In each case indicate what you would observe (e.g. solution changes from colourless to brown, white precipitate forms, brown gas evolved etc).

   a) Samples of hydrogen chloride gas and ammonia gas are mixed.

   b) Ammonia solution is added to copper (II) hydroxide.

   c) Ammonium nitrate solution is boiled with sodium hydroxide solution.

   d) A concentrated ammonia solution is added to a suspension of zinc hydroxide in water

47. For each of the following, describe briefly a test and observation by which you could distinguish between the substances listed. (No equations are necessary)

   a) Potassium chloride and ammonium chloride

   b) Ammonium chloride solution and potassium iodide solution

48. Write brief explanations for the following:

   a) Sodium carbonate is heated in an oven and cooled in a desiccator when used as a primary standard in volumetric analysis.

   b) In the titration of acetic acid with sodium hydroxide, phenolphthalein is a satisfactory indicator but methyl orange is not.

   c) At the equivalence point in a titration between an acetic acid solution and a sodium hydroxide solution, the resulting mixture is basic.

49. Briefly explain the meaning of the following statement. Relate your explanation to a chemical equation describing the system
   "In the production of ammonia by the Haber process, the equilibrium yield is favoured by high pressures and low temperatures."

50. A student used the following procedure to prepare a standard hydrochloric acid solution with a concentration of approximately 0.1 mol L^{-1}.

      Step 1:   Prepared a solution of hydrochloric acid with concentration approximately 0.1 mol L^{-1}

      Step 2:   Standardised the hydrochloric acid by titration against anhydrous sodium carbonate. The hydrochloric acid was in the burette and the sodium carbonate in a conical flask.

a) Explain why the hydrochloric acid was standardised using sodium carbonate instead of sodium hydroxide.

b) Name a suitable indicator for the titration and state the colour change

c) Explain why this particular indicator for this titration was chosen.

51. Briefly describe what is meant by each of the following terms which are used in volumetric analysis:

a) A primary standard

b) An aliquot

c) The equivalence point in a titration.

d) The end-point in a titration.

Old TEE questions:

52. A chemist carries out a titration and records the following figures in her report book

Final reading (mL)	23	22.53	22.59	22.01	22.37	
Initial reading (mL)	0.02	1.07	1.15	1.56	0.89	

What titration figure should she use in her subsequent calculation?

(a) 21.208 mL   (b) 21.21 mL   (c) 21.46 mL   (d) 21.56 mL   (e) 21.562 mL

53. Which one of the following is not used in sulfuric acid manufacture?

(a) $H_2 + S + 2O_2 \rightarrow H_2SO_4$ (b) $4FeS_2 + 11 O_2 \rightarrow 2Fe_2O_3 + 8SO_2$

(c) $S + O_2 \rightarrow SO_2$ (d) $2SO_2 + O_2 \rightarrow SO_2$

(e) $SO_3 + H_2SO_4 \rightarrow H_2S_2O_7$

54. A series of four NaOH solution with different concentration was prepared, and tested with the indicator Brilliant Cresyl Blue. The results are set out below.

pH	Colour with Brilliant Cresyl Blue
10.0	blue
11.0	green
12.0	yellow
13.0	yellow

On the basis of the above experiment, what can you conclude about the pH of two unknown solutions which when tested with Brilliant Cresyl Blue gave the following results?

Unknown solution	Colour with Brilliant Cresyl Blue
A	blue
B	yellow

(a) The pH of A is 10, and the pH of B is 12.

(b) The pH of A is 10, and the pH of B is between 12 and 13

(c) The pH of A is 10, and the pH of B is 12 or more

(d) The pH of A is 10 or less, and the pH of B is between 12 and 13

(e) The pH of A is 10 or less, and the pH of B is 12 or more.

55. A sodium hydroxide solution for use in the Bayer process was analysed as follows. About 20 mL was transferred from the process tank to a 100 mL bottle. From this, 1.000 mL was transferred by pipette to a 250 mL conical flask and titrated with standard 0.2083 mol L^{-1} hydrochloric acid from a burette.
All items of glassware were washed, and given a final rinse before use.
Which one of the following lists the appropriate liquids for the final rinses?

	The 100 mL bottle	The 1.00 mL pipette	The 250 mL conical flask	The burette
(a)	water	water	the NaOH solution	water
(b)	the NaOH solution	the NaOH solution	water	the 0.2083 mol L^{-1} HCl
(c)	water	water	the NaOH solution	the 0.2083 mol L^{-1} HCl
(d)	water	the NaOH solution	the NaOH solution	water
(e)	water	the NaOH solution	water	water

56. a) Write the equation for the industrial synthesis of ammonia.

b) This reaction takes place exceedingly slowly at room temperature and pressure. List three ways in which chemists control reaction conditions to **speed up** the process.

i
ii
iii

57. A solution of diamminesilver chloride, Ag(NH$_3$)$_2$Cl, is prepared by shaking silver chloride with ammonia solution. Excess nitric acid is then added. Which one of the following describes and explains the result?

(a) The solution remains clear because nitrate replaces chloride, giving soluble diamminesilver nitrate.
(b) The solution remains clear because silver nitrate is soluble in water.
(c) The solution remains clear because nitric acid prevents the precipitation of silver hydroxide
(d) A brown precipitate of silver hydroxide is obtained because H$_3$O$^+$ displaces NH$_3$.
(e) A white precipitate of silver chloride is obtained because the acid reacts with the ammonia from the Ag(NH$_3$)$_2$$^+$ ion.

58. Which of the following statements about ammonia is correct?

(a) Ammonia is prepared commercially by the action of sodium hydroxide on ammonium chloride
(b) When ammonia is dissolved in water, NH$_4$OH is precipitated.
(c) When ammonia is heated, the gas NH$_4$$^+$ is evolved.
(d) The salt of ammonia and sulfuric acid is an important fertiliser.
(e) The concentration of ammonia solutions is determined by titration with acetic acid.

59. A dilute solution of ammonia (in the titration vessel) is titrated with dilute hydrochloric acid (from the burette), and the following graph is obtained.
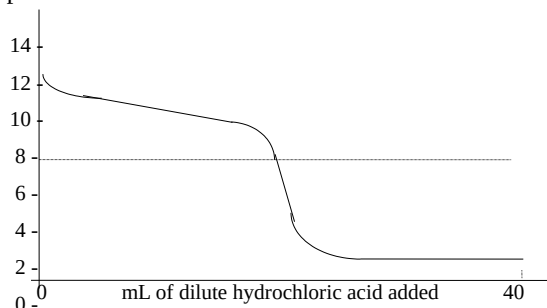
If bromothymol blue, which changes colour around pH of 7, is used as indicator, which of the following statements is **true**?
(a) The end-point occurs before the equivalence point.
(b) the end point occurs at the equivalence point.
(c) The end point occurs after the equivalence point.
(d) There is no equivalence point because it is the wrong indicator.
(e) The colour does not change because it is the wrong indicator

60.   Since strong bases such as NaOH and KOH absorb moisture from the air, they cannot be used in volumetric analysis as primary standards. A standard hydroxide solution can however be prepared by dissolving a known quantity of mercury (II) oxide in excess KBr solution, when the following reaction occurs

$$HgO \ + \ 4 \, Br^- \ + \ H_2O \ \rightarrow HgBr_4{}^{2-} \ + \ 2 \, OH^-$$

When 0.100 mol of HgO is dissolved in a solution of 1.5 mol of KBr in 300 mL of water and the solution made up to 1.0000 L, what is the hydroxide ion concentration in the standard solution?

(a) 0.1000 mol L^{-1} (b) 0.3750 mol L^{-1} (c) 0.4750 mol L^{-1}
(d) 1.600 mol L^{-1} (e) None of these.

61.   An acetic acid solution is titrated with sodium hydroxide solution (in the burette), using methyl orange as the indicator. Which one of the following statements about this titration is true?

(a) The end point and equivalence point occur at the same time.
(b) The end point occurs after the equivalence point.
(c) The end point occurs before the equivalence point.
(d) Whether the end point or equivalence point occurs first depends on the relative concentrations of acid and base.
(e) No end point would be observed at any time.

62.   In a titration procedure, 25.00 mL of a sodium hydroxide solution is diluted to 500.00 mL using a volumetric flask, and 25.00 mL samples transferred by pipette to conical flasks for titration with standard hydrochloric acid from a burette. Which of the following items of glassware

burette,   pipette,   conical flasks,   volumetric flask

can be rinsed with water immediately before use, without making the titrations inaccurate?

(a) The burette and pipette only
(b) The burette, pipette, conical flasks and volumetric flask
(c) The conical flasks only
(d) The conical flasks and volumetric flask only
(e) the volumetric flask only.

63. Write an ionic equation and give the observations for the following reactions
     a) Solid copper (II) hydroxide is shaken with ammonia solution.
     b) Ammonia solution is added to solid silver chloride

ANSWERS

1. a) Na_2CO_3 has a sufficiently constant composition to enable it to be weighed out accurately. NaOH is highly
    deliquescent i.e. it readily absorbs moisture from the atmosphere. Thus, its composition would be continually
    changing whist it was being weighed.
    b) It must be heated in an oven (for about 8 hours at greater than 100^oC) then stored in a desiccator.

2. It must be an acid (for the standardisation of a base)   It must have a stable composition.
    It must be available in a pure form, with a known formula It must have a reasonably high formula mass.

3. a) 47.0 mL
    b) A burette can be used to accurately measure 47.0 mL.
        The 1.00 L solution can be made up in a 1.00 L volumetric flask.
    c) 1.   Wash the burette out with the 1.063 mol L^{-1} HCl solution.
        2.   Fill the burette with the 1.063 mol L^{-1} HCl solution.
        3.   Run 47.0 mL of the HCl solution into a 1 L volumetric flask that had previously been washed with distilled
              water.
        4.   Add distilled water to the volumetric flask, up to the calibrated mark.
        5.   Shake the solution thoroughly.

4. The solid or solution to be put in the volumetric flask is accurately weighed out or measured out prior to it being put
    into the flask. So having a little bit of water present in the flask will not alter the number of moles of the substance
    being added - and water is then to be added to make the final solution up to the calibration mark.

5. If the pipette is rinsed with distilled water, some of this water will remain in the pipette. As a result, the first time
    the pipette is used, the solution drawn up into the pipette will become slightly diluted by this water i.e. the first
    aliquot will contain fewer moles of the reactant.

6. If the burette is rinsed with water, some of this water will remain after the rinsing. As a result, when the solution is
    put into the burette, it will become slightly diluted and so the resulting titres will be larger than they should be.

7. The solution to be put into the conical flask is measured accurately prior to being put into the flask. Consequently,
    it does not matter that it will be diluted when in the flask because this water will not alter the number of molecules of
    solute present.

8.. One characteristic of a primary standard is that the moles of substance present can be accurately calculated from the
    mass of the substance.
    Sodium hydroxide is hygroscopic i.e. it readily absorbs moisture from the atmosphere. Consequently, it is
    impossible, under normal lab conditions, to weigh out the solid NaOH without is absorbing some water and so you
    do not know accurately how many moles of NaOH are present in the weighed sample.

9. The number of water molecules present in the lattice of the hydrated sodium carbonate actually vary depending on
    atmospheric conditions (humidity and temperature). As a result, the formula of the solid can never be accurately
    known and so the molar mass cannot be accurately determined. This means that even though the mass of solid may
    be accurately determined, the moles of sodium carbonate actually present cannot be accurately calculated, which is a
    necessary condition if the substance is to be used as a primary standard.

10. a) 5.30 g   b) F/D, B, G, E, C, H, A

11. Pipette - should be washed with the sodium hydroxide solution prior to use.
    Burette - should be washed with the HCl solution prior to use.

12. The following method assumes that the NaOH solution is put into the burette (it would be just as acceptable to
    put the acetic acid in the burette)
        1. Wash the burette with the NaOH solution.
        2. Fill the burette with the NaOH solution.
        3. Wash the pipette with the acetic acid solution
        4. Pipette an aliquot of the acetic acid solution into a conical flask which had been previously washed with
            distilled water.
        5. Add 3 drops of phenolphthalein (this indicator will change colour at approximately the pH of the equivalence
            point i.e. at a pH of 8 - 9)
        6. Titrate the acetic acid with the NaOH solution until the end point is reached (when the colour changes from
            colourless to pale pink). Note the volume of the NaOH solution used.
        7. Repeat the titration until 3 readings within 0.1 mL of each other are obtained i.e. three concordant results are
            obtained.
        8. Average the concordant results to give the volume of the NaOH solution required to react with the measured
            volume of acetic acid solution.
        9. Carry out the required calculations.

13. a) and d) are incorrect

14. Conclusion c) is correct. (If the solid has lost some of the water of crystallisation, then in the mass of solid dissolved in water, there would be more Na_2CO_3 present than anticipated. Thus, more acid would be required to react with it)

15. a) Bromothymol blue or phenol red (Because at the equivalence point, would have a solution containing NaCl and this would have a pH of about 7. Thus, the indicator would have to change colour at about a pH of 7.)
     b) Bromothymol blue or phenol red. (At the equivalence point, would have a solution of KNO_3 i.e. a pH of approximately 7.)
     c) Phenolphthalein (At the equivalence point, would have a solution of $NaCH_3COO$ i.e. a weak base. Thus the pH would be about 9-10)
     d) Bromocresol green (or perhaps methyl orange or methyl red). (At the equivalence point, would have a solution of NH_4Cl i.e. a weak acid. Thus the pH would be about 4 - 5.)

16. a) i) $OH^- + HClO \rightarrow H_2O + ClO^-$
        ii) 0.125 mol L^{-1} (begin this problem by determining from the graph that 25.0 mL of KOH are required to reach the equivalence point i.e. to react completely with the HClO)
        iii) From the graph, pH = 3.
        iv) A pH of 3 means that the $[H^+] = 10^{-3} = 0.001$ mol L^{-1}. However, the concentration of the HClO solution is 0.125 mol L^{-1}. Thus only a few HClO molecules have ionised in water to form $H^+ + ClO^-$. Therefore the acid can be regarded as a weak acid.
        v) K_a =
     b) i) pH = 8.5
        ii) At the equivalence point, the solution will contain K^+ and ClO^- ions (and water). ClO^-, being the conjugate base of a weak acid, will probably behave as a weak base i.e. some of the ClO^- ions will react with water to form some OH^- ions, to give a weak basic solution of pH 8 - 9. $ClO^- + H_2O \rightleftharpoons HClO + OH^-$
     c) i) Thymol blue. The pH of the equivalence point for the reaction is within the pH range for which this indicator changes colour.

17. a) A larger volume of acid would be used (because the acid would be slightly diluted by the water in the burette). Since conc of HNO_3 = n/V, and V is larger, then the calculated concentrated will be smaller than it should be i.e. a decrease in the estimation of the concentration of HNO_3.
     b) There would be less Na_2CO_3 in the solution pipetted into the titration flask (because the solution is diluted by the water in the pipette). Thus the volume of acid required would be less, and since conc of acid = n/V, the concentration of the acid would appear larger i.e. get an increase in the estimation of the HNO_3 concentration.
     c) This is a correct procedure, as the volume of Na_2CO_3 is accurately measured prior to it being put into the conical flask. The presence of water in this flask will not alter the moles of Na_2CO_3 present i.e. it will have no effect.
     d) $NaHCO_3$ reacts with HNO_3 in a 1:1 ratio ($HCO_3^- + H^+ \rightarrow CO_2 + H_2O$), but Na_2CO_3 reacts in a 1:2 ratio ($CO_3^{2-} + 2H^+ \rightarrow CO_2 + H_2O$). Thus, if some $NaHCO_3$ is present in the sample, a smaller volume of HNO_3 would be required in the titration. Since conc = n/V,   and V is smaller, there would be an increase in the estimation of the concentration of HNO_3.

18. a) sulfur, S or S_8 or   iron pyrites, FeS_2 or any other metal sulfide
     b) $S + O_2 \rightarrow SO_2$,   or $4 FeS_2 + 11 O_2 \rightarrow 2 Fe_2O_3 + 8 SO_2$.
     c) SO_2 and excess air are passed over a suitable catalyst.
     d) An excess of O (air) pushes the equilibrium position of $2SO_2 + O_2 \rightleftharpoons 2SO_3$ towards the right i.e. more SO_3 is formed.
     e) Because the catalyst beds are easily poisoned by impurities.
     f) $2SO_2 + O_2 \rightleftharpoons 2SO_3$
     g) exothermic
     h) Low temperatures favour the formation of SO_3 because according to Le Chatelier's Principle, if the temperature is decreased, the equilibrium position moves to increase the temperature i.e. the exothermic reaction is favoured. High pressure favour the formation of SO_3 because Le Chatelier's principle suggests that at high pressure, the side of the equation with the smaller number of particles (i.e. the RHS in the above equation) will be favoured (in an attempt to decrease the pressure)
     i) Low temperatures are not used because the reaction rate would be too slow. Thus, temperatures of about 400°C are used. A catalyst is also used to increase the reaction rate. The reaction mixture is passed over three catalyst beds, an improved yield of SO_3 being obtained each time. After this process, the reaction is almost 100% complete, so it is not necessary to use very high pressures (this would be an additional expense).
     j) The reaction is exothermic and so the temperature of the reaction mixture increases. But, because the yield of SO_3 is favoured by low temperatures, it is necessary to maintain them at about 400°C. Thus, cooling is necessary.
     k) $SO_3 + H_2O \rightarrow H_2SO_4$

l) The SO_3 is absorbed by concentrated H_2SO_4 to form $H_2S_2O_7$. $SO_3 + H_2SO_4 \rightarrow H_2S_2O_7$.
   The $H_2S_2O_7$ is then added to water to give concentrated H_2SO_4. $H_2S_2O_7 + H_2O \rightarrow 2H_2SO_4$.
m) Production of <u>fertilisers</u> e.g. ammonium sulfate and superphosphate. In the formation of these fertilisers, the
   sulfuric acid act as an acid in its reaction with a base   e.g. $2NH_3 + H_2SO_4 \rightarrow (NH_4)_2SO_4$.
   <u>Electrolyte</u> in car batteries. The sulfuric acid is a good conductor of electricity because it is a strong acid and
   it completely ionises in solution to form many ions. It also participates in the cell reactions (see Redox 2.).
      <u>Cleaning iron</u> before galvanising. The sulfuric acid acts as an acid when it reacts with the rust, a metal oxide.

19. <u>NaOH(aq) + BaCl$_2$(aq)</u> - no reaction occurs because the possible products, $Ba(OH)_2$ and NaCl, are both soluble in
    water. Thus the mixture of solution remains a mixture of solutions i.e. a colourless solution is obtained.
    <u>MgCl$_2$(aq) + NaOH(aq)</u> - a reaction occurs to from the insoluble $Mg(OH)_2$ i.e. a white precipitate forms
      $Mg^{2+} + 2OH^- \rightarrow Mg(OH)_2$.
    <u>ZnCl$_2$(aq) + NaOH(aq)</u> - a reaction occurs to from a the soluble $[Zn(OH)_4]^{2-}$ ion. Thus a colourless solution is
    formed. $Zn^{2+} + 4OH^- \rightarrow [Zn(OH)_4]^{2-}$.

20. When only a small amount of OH^- is present, the reaction $Al^{3+}(aq) + 3OH^-(aq) \rightarrow Al(OH)_3(s)$ occurs and the
    water-insoluble $Al(OH)_3$ forms as a white precipitate. However, this hydroxide is amphoteric and it can react further
    with more OH^- ions to form the water-soluble $[Al(OH)_4]^-$ i.e. a colourless solution is finally obtained
      $Al(OH)_3(s) + OH^-(aq) \rightarrow [Al(OH)_4]^-(aq)$.

21. a) i)   The metal dissolves and a colourless gas and colourless solution are formed.
       ii) $Mg(s) + 2H^+(aq) \rightarrow Mg^{2+}(aq) + H_2(g)$. $Zn(s) + 2H^+(aq) \rightarrow Zn^{2+}(aq) + H_2(g)$.
    b) i)   The magnesium does not react, so the metal remains unchanged in the reaction mixture.
            The zinc reacts to form a colourless gas and a colourless solution; the metal dissolves.
       ii) $Mg + OH^-$ - no reaction
            $Zn(s) + 2OH^-(aq) + 2H_2O(l) \rightarrow [Zn(OH)_4]^{2-}(aq) + H_2(g)$.   (Zn is an amphoteric metal, Mg is not)

22. a) The rate of reaction at $25^{\circ}C$ is extremely slow, thus the mixture takes a very long time to reach equilibrium.
    b) The reaction temperature is increased to about $500^{\circ}C$ and a catalyst is used.
    c) According to Le Chatelier's Principle, one would predict that a low temperature (the reaction is exothermic)
       and a high pressure (R.H.S. of the equation has fewer particles) would give the best yield of ammonia (see
       problem 5.18h) for greater detail)
    d) The reaction mixture that emerges from the reaction chamber contains N_2, H_2 and NH_3. NH_3 has the highest
       boiling point of these three gases, so if the mixture is cooled, the NH_3 will liquefy first (and so separate
       from the rest of the gaseous mixture). The gaseous N_2 and H_2 are then put back into the reaction chamber so
       that they can react further.

23. a) NH_3 undergoes the following reaction when added to water: $NH_3 + H_2O \rightleftharpoons NH_4^+ + OH^-$
       i.e. OH^- is produced. Thus, in ammonia solution the $[OH^-]$ will be greater than 1×10^{-7} and so the $[H_3O^+]$ will
       be less than 10^{-7} e.g. 10^{-9}. That is, the pH will be greater than 7.
    b) When $CuSO_4$ is added to water, Cu^{2+} forms. When ammonia is dissolved in water the following reaction occurs:
       $NH_3 + H_2O \rightleftharpoons NH_4^+ + OH^-$. In the presence of ammonia, the Cu^{2+} reacts with the OH^- ions to form:
       $Cu^{2+} + 2OH^- \rightarrow Cu(OH)_2$. $Cu(OH)_2$ is insoluble and pale blue in colour. However, if a lot of NH_3 is
       present, a further reaction occurs: $Cu(OH)_2 + 4NH_3 \rightarrow Cu(NH_3)_4^{2+} + 2OH^-$. $Cu(NH_3)_4^{2+}$ is soluble in
        water and is deep blue in colour.
    c) Al^{3+} reacts with the OH^- present in the ammonia solution i.e. $Al^{3+} + 3OH^- \rightarrow Al(OH)_3$, and forms a white
       insoluble solid, $Al(OH)_3$.   The aluminium hydroxide does not react further with the ammonia solution.

24. a) React KOH with HNO_3, using the indicator to show when they are present in equivalent amounts (pH = 7), to
       form $KNO_3 + H_2O$. The KOH would be first dissolved in water, the HNO_3 would then be added, and the
       mixture evaporated to give solid KNO_3.
       React $Ca_3(PO_4)_2$ with HNO_3, again using the indicator to show when sufficient acid has been added, to form
       water-soluble $Ca(H_2PO_4)_2$.   The solution formed from this react would be evaporated to form solid $Ca(H_2PO_4)_2$.
       The two solids could then be mixed to form a fertiliser rich in potassium, nitrogen and phosphorus.
    b) $OH^- + H^+ \rightarrow H_2O$ then $K^+(aq) + NO_3^-(aq) \rightarrow KNO_3(s)$
       $Ca_3(PO_4)_2 + 4H^+ \rightarrow 3Ca^{2+} + 2H_2PO_4^-$.   then $Ca^{2+}(aq) + 2H_2PO_4^-(aq) \rightarrow Ca(H_2PO_4)_2(s)$

25 a. $NH_3(g) + HCl(g) \rightarrow NH_4Cl(s)$ - white smoke forms
    b. $Zn(s) + 2H^+(aq) \rightarrow H_2(g) + Zn^{2+}(aq)$ - colourless gas and colourless solution form
    c $OH^-(aq) + H^+(aq) \rightarrow H_2O(l)$ - no observable change - colourless solution remains
    d. $CaCO_3(s) + 2H^+(aq) \rightarrow CO_2(g) + H_2O(l) + Ca^{2+}(aq)$ - colourless gas and colourless solution form
    e. $2H^+(aq) + S^{2-}(aq) \rightarrow H_2S(g)$ - colourless gas with unpleasant odour (rotten egg smell) forms
    f. $Na_2SO_3(s) + 2H^+(aq) \rightarrow SO_2(g) + H_2O(l) + 2Na^+(aq)$ - colourless gas with pungent odour and colourless
                                                     solution form

g. $Al_2O_3(s) + 6H^+(aq) \rightarrow 2Al^{3+}(aq) + 3H_2O(l)$ - colourless solution forms

h. $H^+(aq) + NH_3(aq) \rightarrow NH_4^+(aq)$ - no observable change - colourless solution remains, ammonia smell disappears

i. $H_2(g) + Cl_2(g) \rightarrow HCl(g)$

j. $S(s) + O_2(g) \rightarrow SO_2(g)$

k. $2SO_2(g) + O_2(g) \rightarrow 2SO_3(g)$

l. $SO_3(g) + H_2SO_4(l) \rightarrow H_2S_2O_7(l)$

m. $H^+(aq) + NH_3(aq) \rightarrow NH_4^+(aq)$

n. $Mg(s) + 2H^+(aq) \rightarrow H_2(g) + Mg^{2+}(aq)$ - colourless gas and colourless solution form

o. $Mg(s) + 4H^+(aq) + SO_4^{2}(aq)^- \rightarrow Mg^{2+}(aq) + SO_2(g) + 2H_2O(l)$ - colourless solution and colourless gas with pungent odour form

p. no reaction

q. $Cu(s) + 4H^+(aq) + 2NO_3^-(aq)^- \rightarrow Cu^{2+}(aq) + 2NO_2(g) + 2H_2O(l)$ - blue solution and brown gas with pungent odour form

r. $H^+(aq) + NH_3(aq) \rightarrow NH_4^+(aq)$

s. $OH^-(aq) + H^+(aq) \rightarrow H_2O(l)$

t. $SO_2(g) + 2OH^-(aq) \rightarrow SO_3^{2-}(aq) + H_2O(l)$

u. $CO_2(g) + 2OH^-(aq) \rightarrow CO_3^{2-}(aq) + H_2O(l)$

v. $Al(OH)_3(s) + OH^-(aq) \rightarrow Al(OH)_4^-(aq)$ - colourless solution forms

w. $Al(OH)_3(s) + 3H^+(aq) \rightarrow Al^{3+}(aq) + 3H_2O(l)$ - colourless solution forms

x. $Al^{3+}(aq) + 4OH^-(aq) \rightarrow Al(OH)_4^-(aq)$ - (white precipitate initially forms but it dissolves and) colourless solution forms

y. no reaction   - white solid remains undissolved

z. $Mg(OH)_2 + 2H^+(aq) \rightarrow Mg^{2+} + 2H_2O(l)$ - colourless solution forms

A. $Mg^{2+}(aq) + 2OH^-(aq) \rightarrow Mg(OH)_2(s)$ - white precipitate forms

B. $Zn(OH)_2(s) + 2OH^-(aq) \rightarrow Zn(OH)_4^{2-}(aq)$ - colourless solution forms

C. $Zn^{2+}(aq) + 4OH^-(aq) \rightarrow Zn(OH)_4^{2-}(aq)$ - (white precipitate initially forms but it dissolves and) colourless solution forms

D. $Cr(OH)_3(s) + OH^-(aq) \rightarrow Cr(OH)_4^-(aq)$ - dark green solution forms

E. $Cr^{3+}(aq) + 4OH^-(aq) \rightarrow Cr(OH)_4^-(aq)$ - (green precipitate initially forms but it dissolves and) dark green solution forms

F. no reaction   - green-blue solid remains undissolved

G. $Cu^{2+}(aq) + 2OH^-(aq) \rightarrow Cu(OH)_2(s)$ - blue precipitate forms

H. $Fe^{3+}(aq) + 3OH^-(aq) \rightarrow Fe(OH)_3(s)$ - orange precipitate forms

I. no reaction

J. $2Cr(s) + 2OH^-(aq) + 6H_2O(l) \rightarrow 3H_2(g) + 2Cr(OH)_4^-(aq)$ - colourless gas and dark green solution form

K. $Zn(s) + 2OH^-(aq) + 2H_2O(l) \rightarrow H_2(g) + Zn(OH)_4^{2-}(aq)$ - colourless gas and colourless solution form

L. $2Al(s) + 2OH^-(aq) + 6H_2O(l) \rightarrow 3H_2(g) + 2Al(OH)_4^-(aq)$ - colourless gas and colourless solution form

M. $Al_2O_3(s) + 2OH^-(aq) + 3H_2O(l) \rightarrow 2Al(OH)_4^-(aq)$ - colourless solution forms

N. $N_2(g) + 3H_2(g) \rightarrow 2NH_3(g)$

O. $NH_3(g) + H_2O(l) \rightleftharpoons NH_4^+(aq) + OH^-(aq)$

P. $Mg^{2+}(aq) + 2OH^-(aq) \rightarrow Mg(OH)_2(s)$ - white precipitate forms

Q. $Fe^{3+}(aq) + 3OH^-(aq) \rightarrow Fe(OH)_3(s)$- orange precipitate forms

R. $Al^{3+}(aq) + 3OH^-(aq) \rightarrow Al(OH)_3(s)$- white precipitate forms

S. no reaction

T. $Cu^{2+}(aq) + 4NH_3(aq) \rightarrow Cu(NH_3)_4^{2+}(aq)$ - (blue precipitate forms which dissolves and) dark blue solution forms

U. $Zn^{2+}(aq) + 4NH_3(aq) \rightarrow Zn(NH_3)_4^{2+}(aq)$ - (white precipitate forms which dissolves and) colourless solution forms

V. $Cu(OH)_2(s) + 4NH_3(aq) \rightarrow Cu(NH_3)_4^{2+}(aq) + 2OH^-(aq)$ - dark blue solution forms

W. $Ag_2O(s) + 2NH_3(aq) + H_2O(l) \rightarrow 2Ag(NH_3)_2^+(aq) + 2OH^-(aq)$ - colourless solution forms

X. $Fe^{2+}(aq) + 2OH^-(aq) \rightarrow Fe(OH)_2(s)$ - pale green precipitate forms

26. D	27. D	28. A	29. A	30. D
31. A	32. D	33. D	34. C	35. D
36. C	37. D	38. B	39. B	40. D
41. B	42. C	43. C		

44. Anhydrous sodium carbonate has a known composition/formula, which does not change if left exposed to the atmosphere for a short time. However, sodium hydroxide absorbs moisture from the atmosphere, and thus changes its composition as it is being weighed. A primary standard must have a known composition.

45. Solid sodium carbonate will slowly absorb some moisture from the atmosphere. Thus, the heating is to drive off any of this absorbed water. The anhydrous solid is then stored in a desiccator to prevent it from reabsorbing any moisture.

46. a) $HCl(g)$ + $NH_3(g)$ → $NH_4Cl(s)$ White smoke formed
  b) $Cu(OH)_2(s)$ + $4NH_3(aq)$ → $Cu(NH_3)_4^{2+}(aq)$ + $2OH^-(aq)$ Solid dissolves to give deep blue solution.
  c) $NH_4^+(aq)$ + $OH^-(aq)$ → $NH_3(aq)$ + $H_2O(l)$ Smell of ammonia develops.
  d) $Zn(OH)_2(s)$ + $4NH_3(aq)$ → $Zn(NH_3)_4^{2+}(aq)$ + $2OH^-(aq)$ Solid dissolves to form colourless solution.

47. a) Add a solution of sodium hydroxide. Both solids will dissolve. The potassium chloride will not react, but the ammonium chloride will form a solution which smells like ammonia.
  b) Add a solution of sodium hydroxide. The ammonium chloride will produce a solution which has the smell of ammonia. This smell will not exist for potassium iodide

48 a) Sodium carbonate absorbs moisture slowly from the atmosphere, and once this happens, its exact composition is not known, and it may vary depending on the temperature etc. So when it is used as a primary standard, the anhydrous form i.e. the   form without any water molecules present, is used. Thus before use, the sodium carbonate must be heated to ensure that all the water of crystallisation has been removed. It is then stored in a desiccator to ensure that it remains "dry".
  b) The equivalence point of a titration of a weak acid with a strong base will be at about pH of 8-10. Thus an indicator which will give an end point of this pH range is required. Phenolphthalein changes colour within this range. Methyl orange changes colour within the range of pH 3 - 5. Thus methyl orange is not suitable.
  c) At the equivalence point in this titration, a solution of sodium acetate will be present. The sodium ions will not affect the pH, but the acetate ions can hydrolyse to form OH^- ions, thus making the solution basic.
$$CH_3COO^- + H_2O \rightleftharpoons CH_3COOH + OH^-.$$

49. $N_2(g)$ + $3H_2(g)$ $\rightleftharpoons$ $2NH_3(g)$ ΔH negative
Because the reaction is exothermic, if the temperature is decreased, the equilibrium position will be shifted further towards the products i.e. to form more ammonia. In the reaction, 4 particles react to form 2 particles, then if the pressure is increased, the equilibrium position will shift in an attempt to decrease the number of particles i.e. to form more ammonia. That is, the production of ammonia will be favoured by a low temperature and a high pressure.

50. a) The composition of sodium hydroxide changes when the solid is exposed to air; the sodium hydroxide readily absorbs moisture from the atmosphere. Thus, when sodium hydroxide is weighed out, its accurate atomic mass is not known. However, the composition of anhydrous sodium carbonate remains constant for sufficient time to weigh out a sample of this solid, which can then be used in the titration. It is necessary to know the accurate molar mass of these substances because the number of moles of substance involved in the titration is calculated using the mass and molar mass.
  b) Methyl orange. If sodium carbonate is in the conical flask, the initial colour will be yellow, and this will change to red during the titration.
  c) The titration involves a strong acid reacting with a weak base. Thus, at the equivalence point, a solution of a weak acid (CO_2 in water) will be present. It is necessary to use an indicator that will change colour at the pH of this weak acid solution. The pH would be about 3 and the indicator that changes colour at this pH is methyl orange.

51. a) A solid, of known composition, which can be weighed out without its composition changing. It must be 100% pure, and have a "highish" molar mass. It also must be soluble in water so that its solution can be used in a titration.
  b) The volume of liquid measured and delivered by a pipette.
  c) The point in a titration where the two reactant are present in stoichiometric amounts as shown in the balanced equation for the reaction.
  d) The point in a titration when the indicator changes colour.

52. (c)   53.   (a)   54. (e)   55.   (b)
56. a) $N_2(g)$ + $3H_2(g)$ $\rightleftharpoons$ $2NH_3(g)$
  b) i use a catalyst - iron/iron oxide catalyst   ii use high pressure - of about 350 atm
    iii use intermediate/high temperature - of about 500^0C

57. (e)   58. (d)   59. (a)   60. (e)   61. (c)   62. (d)

63. a) $Cu(OH)_2(s)$ + $4NH_3(aq)$ → $Cu(NH_3)_2^{2+}(aq)$ + $2OH^-(aq)$ - green solid dissolves to form a dark blue solution
  b) $AgCl(s)$ + $2NH_3(aq)$ → $Ag(NH_3)_2^+(aq)$ + $Cl^-(aq)$ - white solid dissolves to form colourless solution