Chapter 8

Acids, bases and salts

8.1 Thecharacteristic properties of acids and bases

01. 0620_s21_qp_42 Q: 5

This question is about compounds of nitrogen.

(a) Nitrogen reacts with lithium to form lithium nitride, Li_3N.

(i) Write the chemical equation for the reaction between lithium and nitrogen.

..... [2]

(ii) Lithium nitride is ionically bonded.

Complete the diagram to show the electronic structure of the nitride ion.
Show the charge on the nitride ion.

.....

[2]

(b) Nitrogen reacts with fluorine to form nitrogen trifluoride, NF_3.

(i) The chemical equation can be represented as shown.

$$N{\equiv}N + 3\ F{-}F \rightarrow 2\ F{-}\underset{\displaystyle F}{\underset{|}{N}}{-}F$$

Some bond energies are shown in the table.

bond	bond energy in kJ / mol
N≡N	945
F–F	160
N–F	300

Calculate the energy change for the reaction between nitrogen and fluorine, using the following steps:

- energy taken in to break bonds

..... kJ

- energy released when bonds are formed

..... kJ

- energy change during the reaction.

..... kJ / mol
[3]

(ii) Use your answer to **(i)** to deduce whether this reaction is endothermic or exothermic. Explain your answer.

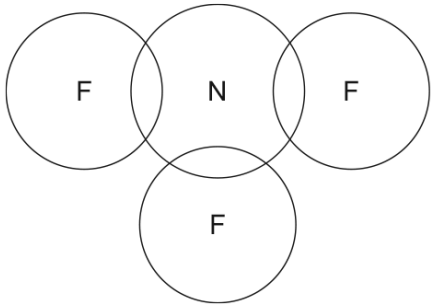
.....

..... [1]

(iii) Complete the dot-and-cross diagram to show the electron arrangement in a molecule of NF_3.

Use dots for nitrogen electrons and crosses for fluorine electrons.

Show outer electrons only.



[3]

(c) Lithium nitride melts at 813 °C. Nitrogen trifluoride melts at –206 °C.

Explain in terms of attractive forces why lithium nitride has a much higher melting point than nitrogen trifluoride.

In your answer refer to the types of attractive forces between particles and their relative strengths.

.....

.....

.....

..... [3]

(d) Ammonium nitrate, NH_4NO_3, is a compound of nitrogen.

(i) Calculate the percentage by mass of nitrogen in ammonium nitrate.

percentage by mass of nitrogen = ... [2]

(ii) State a use of ammonium nitrate in agriculture.

..... [1]

(iii) State the name of a compound that will displace ammonia from ammonium nitrate.

..... [1]

(e) Ammonia is a base which forms a weakly alkaline solution when dissolved in water.

(i) Define the term *base*.

..... [1]

(ii) Suggest the pH of aqueous ammonia.

..... [1]

[Total: 20]

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02. 0620_w21_qp_42 Q: 2

Acids are important laboratory chemicals.

(a) Some acids completely dissociate in water to form ions.

(i) State the term applied to acids that completely dissociate in water.

..... [1]

(ii) Complete the equation to show the complete dissociation of sulfuric acid in water.

$H_2SO_4 \rightarrow$ ..... [2]

(iii) State the colour of methyl orange in sulfuric acid.

..... [1]

(b) The equation for the reaction between powdered zinc carbonate and dilute nitric acid is shown.

$ZnCO_3$..... + $2HNO_3$..... $\rightarrow$ $Zn(NO_3)_2$..... + H_2O..... + CO_2.....

(i) Complete the equation by adding state symbols. [2]

(ii) A student found that 2.5 g of zinc carbonate required 20 cm^3 of dilute nitric acid to react completely.

Calculate the concentration of dilute nitric acid using the following steps:

- calculate the mass of 1 mole of $ZnCO_3$

..... g

- calculate the number of moles of $ZnCO_3$ reacting

..... moles

- determine the number of moles of HNO_3 reacting

..... moles

- calculate the concentration of HNO_3.

..... mol/dm^3

[4]

[Total: 10]

03. 0620_s20_qp_41 Q: 4

This question is about reactions of bases and acids.

(a) Ammonia is a gas at room temperature.

What is the test for ammonia gas? Describe the positive result of this test.

test .....

result .....

[2]

(b) Ammonia reacts with water to form ions.

$$NH_3 + H_2O \rightleftharpoons NH_4^+ + OH^-$$

(i) How does this equation show that ammonia, NH_3, behaves as a base?

..... [1]

(ii) Aqueous ammonia is described as a weak base.

Suggest the pH of aqueous ammonia.

pH = ... [1]

(iii) Describe what is seen when aqueous ammonia is added to aqueous copper(II) sulfate, until no further change is seen.

.....

.....

..... [3]

(c) Aqueous sodium hydroxide, NaOH(aq), is a strong alkali that reacts with dilute sulfuric acid exothermically.

(i) What type of reaction is this?

..... [1]

(ii) Complete the equation for the reaction between aqueous sodium hydroxide and dilute sulfuric acid.

$2NaOH + H_2SO_4 \rightarrow$ ..... + ...

[2]

(d) A student wanted to find the concentration of some dilute sulfuric acid by titration. The student found that 25.0 cm^3 of 0.0400 mol/dm^3 NaOH(aq) reacted exactly with 20.0 cm^3 of H_2SO_4(aq).

(i) Name a suitable indicator to use in this titration.

..... [1]

(ii) Calculate the concentration of the H_2SO_4(aq) in mol/dm^3 using the following steps.

- Calculate the number of moles of NaOH in 25.0 cm^3.

moles = ...

- Deduce the number of moles of H_2SO_4 that reacted with the 25.0 cm^3 of NaOH(aq).

moles = ...

- Calculate the concentration of H_2SO_4(aq) in mol/dm^3.

concentration = ... mol/dm^3

[3]

(iii) Calculate the concentration of the 0.0400 mol/dm^3 NaOH(aq) in g/dm^3.

concentration = ... g/dm^3 [2]

[Total: 16]

04. 0620_s19_qp_42 Q: 3

This question is about phosphorus and compounds of phosphorus.

(a) Phosphorus has the formula P_4. Some properties of P_4 are shown.

melting point/°C	45
boiling point/°C	280
electrical conductivity	non-conductor
solubility in water	insoluble

(i) Name the type of bonding that exists between the atoms in a P_4 molecule.

..... [1]

(ii) Explain, in terms of attractive forces between particles, why P_4 has a low melting point.

.....

..... [1]

(iii) Explain why phosphorus is a non-conductor of electricity.

.....

..... [1]

(b) Phosphorus, P_4, reacts with air to produce phosphorus(V) oxide, P_4O_{10}.

(i) Write a chemical equation for this reaction.

..... [2]

(ii) What type of chemical reaction is this?

..... [1]

(c) Phosphorus(V) oxide, P_4O_{10}, is an acidic oxide.

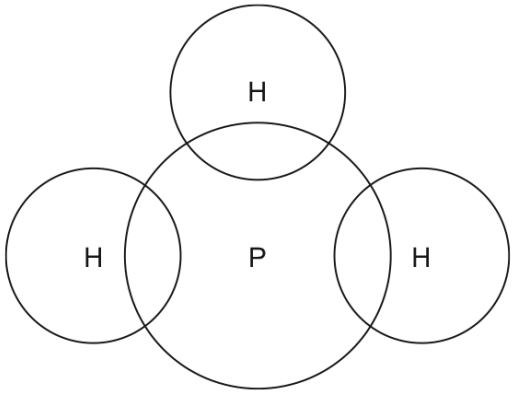
Phosphorus(V) oxide, P_4O_{10}, reacts with aqueous sodium hydroxide to form a salt containing the phosphate ion, PO_4^{3-}. Water is the only other product.

Write a chemical equation for the reaction between phosphorus(V) oxide and aqueous sodium hydroxide.

..... [2]

(d) Phosphine has the formula PH_3.

Complete the dot-and-cross diagram to show the electron arrangement in a molecule of phosphine. Show outer shell electrons only.



[2]

(e) Phosphine, PH_3, has a similar chemical structure to ammonia, NH_3.

Ammonia acts as a base when it reacts with sulfuric acid.

(i) What is meant by the term *base*?

..... [1]

(ii) Write a chemical equation for the reaction between ammonia and sulfuric acid.

..... [2]

[Total: 13]

05. 0620_s16_qp_43 Q: 5

Dilute hydrochloric acid reacts with sodium carbonate solution.

$$2HCl(aq) + Na_2CO_3(aq) \rightarrow 2NaCl(aq) + H_2O(l) + CO_2(g)$$

(a) Explain why effervescence is seen during the reaction.

.....

..... [1]

(b) Dilute hydrochloric acid was titrated with sodium carbonate solution.

- 10.0 cm^3 of 0.100 mol/dm^3 hydrochloric acid were placed in a conical flask.
- A few drops of methyl orange indicator were added to the dilute hydrochloric acid.
- The mixture was titrated with sodium carbonate solution.
- 16.2 cm^3 of sodium carbonate solution were required to react completely with the acid.

(i) What colour would the methyl orange indicator be in the hydrochloric acid?

..... [1]

(ii) Calculate how many moles of hydrochloric acid were used.

..... mol [1]

(iii) Use your answer to **(b)(ii)** and the equation for the reaction to calculate the number of moles of sodium carbonate that reacted.

..... mol [1]

(iv) Use your answer to **(b)(iii)** to calculate the concentration of the sodium carbonate solution in mol/dm^3.

..... mol/dm^3 [2]

(c) In another experiment, 0.020 mol of sodium carbonate were reacted with excess hydrochloric acid.

Calculate the maximum volume (at r.t.p.) of carbon dioxide gas that could be made in this reaction.

..... dm^3 [3]

[Total: 9]

06. 0620_w14_qp_31 Q: 1

(a) Match the following pH values to the solutions given below.

1 3 7 10 13

The solutions all have the same concentration.

solution	**pH**
aqueous ammonia, a weak base	.....
dilute hydrochloric acid, a strong acid	.....
aqueous sodium hydroxide, a strong base	.....
aqueous sodium chloride, a salt	.....
dilute ethanoic acid, a weak acid	.....

[5]

(b) Explain why solutions of hydrochloric acid and ethanoic acid with the same concentration, in mol / dm^3, have a different pH.

.....

.....

..... [2]

(c) Measuring pH is one way of distinguishing between a strong acid and a weak acid. Describe another method.

method .....

.....

results .....

.....

[2]

[Total: 9]

07. 0620_w13_qp_31 Q: 6

Lead is an excellent roofing material. It is malleable and resistant to corrosion. Lead rapidly becomes coated with basic lead carbonate which protects it from further corrosion.

(a) Lead has a typical metallic structure which is a lattice of lead ions surrounded by a 'sea' of mobile electrons. This structure is held together by attractive forces called a metallic bond.

(i) Explain why there are attractive forces in a metallic structure.

.....

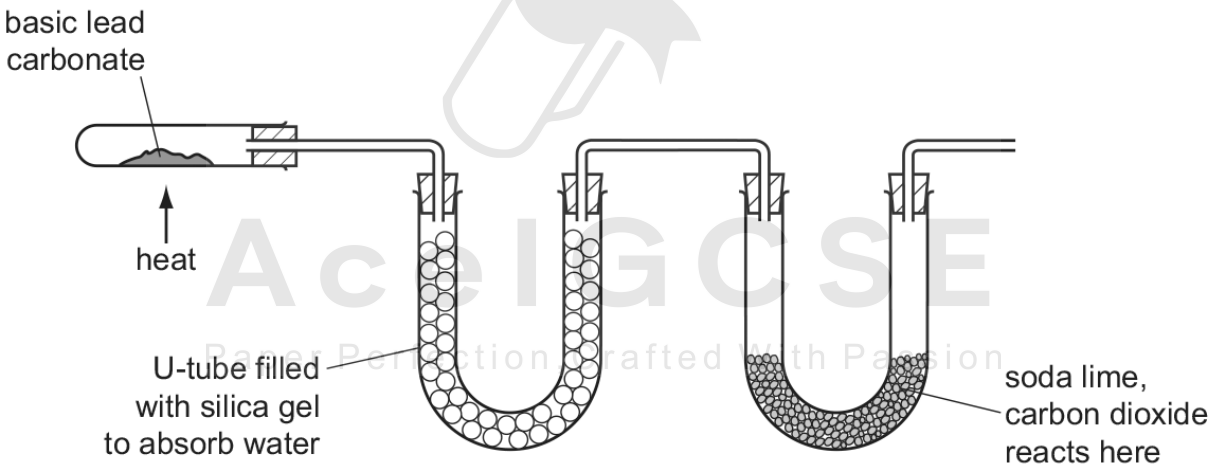
..... [2]

(ii) Explain why a metal, such as lead, is malleable.

.....

..... [2]

(b) Basic lead(II) carbonate is heated in the apparatus shown below. Water and carbon dioxide are produced.



(i) Silica gel absorbs water. Silica gel often contains anhydrous cobalt(II) chloride. When this absorbs water it changes from blue to pink.
Suggest a reason.

..... [1]

(ii) Soda lime is a mixture of sodium hydroxide and calcium oxide. Why do these two substances react with carbon dioxide?

.....

..... [2]

(iii) Name **two** substances formed when soda lime reacts with carbon dioxide.

..... [2]

(c) Basic lead(II) carbonate has a formula of the type $xPbCO_3.yPb(OH)_2$ where x and y are whole numbers.
Determine x and y from the following information.

$$PbCO_3 \rightarrow PbO + CO_2$$

$$Pb(OH)_2 \rightarrow PbO + H_2O$$

When heated, the basic lead(II) carbonate gave 2.112 g of carbon dioxide and 0.432 g of water.

Mass of one mole of CO_2 = 44 g
Mass of one mole of H_2O = 18 g

Number of moles of CO_2 formed = ... [1]

Number of moles of H_2O formed = ... [1]

x = ... and y = ...

Formula of basic lead(II) carbonate is ..... [1]

[Total: 12]

01. 0620_s21_ms_42 Q: 5

Question	Answer	Marks
(a)(i)	$6Li + N_2 \rightarrow 2Li_3N$ N_2 as reactant (1) rest of equation (1)	2
(a)(ii)	new octet of 8 electrons consisting of 5 crosses and 3 dots in second shell (1) charge of 3– (1)	2

Question	Answer	Marks
(b)(i)	bonds broken [945 + (3 × 160)] = 1425 (1) bonds formed (2 × 3 × 300) = 1800 (1) energy change = M1 – M2 = 1425 – 1800 = –375 (1)	3
(b)(ii)	*Answer must reflect answer in **5(b)(i)*** exothermic **and** more energy released (in bond formation) than used/taken in (in bond breaking)	1
(b)(iii)	N with 1 bonding pair with each F (1) 2 non-bonding dots for N (1) 6 non-bonding crosses for F (1)	3
(c)	ionic bonds in Li_3N (1) attraction between molecules in NF_3 (1) weaker attraction (between particles) in NF_3 ORA (1)	3
(d)(i)	rfm of NH_4NO_3 = 80 (1) mass of N = 2 × 14 = 28 and percentage N = 100 × 28 / 80 = 35% (1)	2
(d)(ii)	fertiliser	1
(d)(iii)	calcium hydroxide	1
(e)(i)	proton acceptor	1
(e)(ii)	$7 < x \leqslant 11$	1

02. 0620_w21_ms_42 Q: 2

Question	Answer	Marks
(a)(i)	strong	1
(a)(ii)	$2H^+ + SO_4^{2-}$ H^+ (1) correct equation (1)	2
(a)(iii)	pink / red	1
(b)(i)	$ZnCO_3$**(s)** + $2HNO_3$**(aq)** → $Zn(NO_3)_2$**(aq)** + H_2O**(l)** + CO_2**(g)** reactant states (1) product states (1)	2
(b)(ii)	M1 125 M2 2.5 / 125 = 0.02(00) M3 0.02(00) × 2 = 0.04(00) M4 0.04(00) × 1000 / 20 = 2(.00)	4

03. 0620_s20_ms_41 Q: 4

(a)	(damp) litmus	1
	(turns) blue	1
(b)(i)	proton acceptor	1
(b)(ii)	Above pH 7 up to 11	1
(b)(iii)	blue precipitate	1
	precipitate dissolves	1
	deep blue solution remains	1
(c)(i)	neutralisation	1
(c)(ii)	Na_2SO_4	1
	$2H_2O$	1
(d)(i)	methyl orange	1
(d)(ii)	M1 mol of NaOH $= 0.0400 \times \frac{25.0}{1000} = 0.001(00)$ mol M2 mol of $H_2SO_4 = \frac{M1}{2} = \frac{0.001}{2} = 0.0005(00)$ M3 M2 $\times \frac{1000}{20.0} = 0.0005 \times \frac{1000}{20.0} = 0.025$ (mol / dm^3) allow ecf	3
(d)(iii)	M1 use of 40 g/mol M2 $40 \times 0.04 = 1.6$ (g/dm^3)	2

04. 0620_s19_ms_42 Q: 3

(a)(i)	covalent	1
(a)(ii)	forces of attraction between molecules **AND** are weak / need a small amount of energy to break	1
(a)(iii)	no **moving** or **flowing** or **mobile charged particles** or **ions** or **electrons**	1
(b)(i)	$P_4 + 5O_2 \rightarrow P_4O_{10}$ **M1** all formulae correct (1) **M2** equation correctly balanced (1)	2
(b)(ii)	redox / combustion	1
(c)	$P_4O_{10} + 12NaOH \rightarrow 4Na_3PO_4 + 6H_2O$ **M1** Na_3PO_4 (1) **M2** equation completely correct (1)	2
(d)	**M1** 3 pairs of bonding electrons (1) **M2 only** 1 lone pair on P (1)	2
(e)(i)	proton / H^+ / hydrogen ion acceptor	1
(e)(ii)	$2NH_3 + H_2SO_4 \rightarrow (NH_4)_2SO_4$ **M1** $(NH_4)_2SO_4$ (1) **M2** equation completely correct (1)	2

05. 0620_s16_ms_43 Q: 5

(a)	carbon dioxide / a gas is made;	1
(b)(i)	red;	1
(b)(ii)	0.001;	1
(b)(iii)	0.0005;	1
(b)(iv)	0.031 (2 marks) **M1 (iii)** / 0.0162;	2
(c)	0.48 (dm^3) **M1** moles carbon dioxide = 0.02; **M2** volume carbon dioxide = 0.02 × 24; **M3** = 0.48 (dm^3);	3 1 1 1

06. 0620_w14_ms_31 Q: 1

(a) Match the following pH values to the solutions given below.

1 3 7 10 13
The solutions all have the same concentration.

solution	**pH**
aqueous ammonia, weak base	10
dilute hydrochloric acid, a strong acid	1
aqueous sodium hydroxide, a strong base	13
aqueous sodium chloride, a salt	7
dilute ethanoic acid, a weak acid	3

[5]

(b) Hydrochloric acid strong acid **or** ethanoic acid weak acid [1]
OR: hydrochloric acid completely ionised **or** ethanoic acid partially ionised
hydrochloric acid greater concentration of/more H^+ ions (than ethanoic acid) [1]

(c) Rate of reaction with Ca, Mg, Zn, Fe [1]

Strong (hydrochloric) acid bubbles faster **or** more bubbles **or** dissolves faster [1]

OR: rate of reaction with (metal) carbonate [1]
strong (hydrochloric) acid faster **or** more bubbles **or** dissolves faster (only if carbonate insoluble) [1]

OR: electrical conductivity [1]
strong (hydrochloric) acid better conductor [1]

[Total: 9]

07. 0620_w13_ms_31 Q: 6

(a) (i) (attractive force between) positive ions [1]
and (negative) electrons [1]
opposite charges attract ONLY [1]
electrostatic attraction ONLY [1]

(ii) lattice / rows / layers of lead ions / cations / positive ions [1]
NOT: atoms / protons / nuclei
can slide past each other / the bonds are non-directional [1]

(b) (i) anhydrous cobalt chloride becomes hydrated [1]
ACCEPT: hydrous

(ii) carbon dioxide is acidic [1]
sodium hydroxide and calcium oxide are bases / alkalis [1]

(iii) Any two of:
water, calcium carbonate and sodium carbonate [2]
ACCEPT: sodium bicarbonate

(c) number of moles of CO_2 formed = 2.112 / 44 = 0.048 [1]
number of moles of H_2O formed = 0.432 / 18 = 0.024 [1]

x = 2 and y = 1 **NOT:** ecf from this line

formula is $2PbCO_3.Pb(OH)_2$ / $Pb(OH)_2.2PbCO_3$ [1]

[Total:12]