SL Paper 2

Boron is most often encountered as a component in borosilicate glass (heat resistant glass).

The naturally occurring element contains two stable isotopes, $^{10}_{5}\mathrm{B}$ and $^{11}_{5}\mathrm{B}$.

a. State the number of protons, neutrons and electrons in an atom of $^{11}_{5}\mathrm{B}$. [1]

	Protons	Neutrons	Electrons
$^{11}_{5}\mathrm{B}$			

b. The relative atomic mass of boron is 10.8, to three significant figures. Calculate the percentage of $^{10}_{5}\mathrm{B}$ in the naturally occurring element. [2]

c. Isotopes of boron containing 7 and 8 neutrons also exist. Suggest why releasing isotopes containing more neutrons than the stable isotope into the environment can be dangerous. [1]

d. (i) State the formula of the compound that boron forms with fluorine. [3]

(ii) Explain why this compound acts as a Lewis acid.

Ammonia, $\mathrm{NH_3}$, is a base according to both the Brønsted–Lowry and the Lewis theories of acids and bases.

The equation for the reaction between sodium hydroxide, NaOH, and nitric acid, $\mathrm{HNO_3}$, is shown below.

$$\mathrm{NaOH(aq) + HNO_3(aq) \rightarrow NaNO_3(aq) + H_2O(l)} \quad \Delta H = -57.6\ \mathrm{kJ\,mol^{-1}}$$

a. Distinguish between the terms *strong base* and *weak base*, and state one example of each. [3]

b.i. State the equation for the reaction of ammonia with water. [1]

b.ii. Explain why ammonia can act as a Brønsted–Lowry base. [1]

b.iii. Explain why ammonia can also act as a Lewis base. [1]

c. (i) When ammonium chloride, $\mathrm{NH_4Cl(aq)}$, is added to excess solid sodium carbonate, $\mathrm{Na_2CO_3(s)}$, an acid–base reaction occurs. Bubbles of gas are produced and the solid sodium carbonate decreases in mass. State **one** difference which would be observed if nitric acid, $\mathrm{HNO_3(aq)}$, was used instead of ammonium chloride. [5]

(ii) Deduce the Lewis structures of the ammonium ion, $\mathrm{NH_4^+}$, and the carbonate ion, $\mathrm{CO_3^{2-}}$.

Ammonium ion Carbonate ion

(iii) Predict the shapes of $\mathrm{NH_4^+}$ and $\mathrm{CO_3^{2-}}$.

$\mathrm{NH_4^+}$:

$\mathrm{CO_3^{2-}}$:

d. (i) Sketch and label an enthalpy level diagram for this reaction. [6]

(ii) Deduce whether the reactants or the products are more energetically stable, stating your reasoning.

(iii) Calculate the change in heat energy, in kJ, when $50.0\ \mathrm{cm^3}$ of $2.50\ \mathrm{mol\,dm^{-3}}$ sodium hydroxide solution is added to excess nitric acid.

e. When 5.35 g ammonium chloride, $\mathrm{NH_4Cl(s)}$, is added to $100.0\ \mathrm{cm^3}$ of water, the temperature of the water decreases from 19.30 °C to 15.80 °C. Determine the enthalpy change, in $\mathrm{kJ\,mol^{-1}}$, for the dissolving of ammonium chloride in water. [3]

When nitrogen gas and hydrogen gas are allowed to react in a closed container, the following equilibrium is established.

$$\mathrm{N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)} \qquad \Delta H = -92.6\ \mathrm{kJ}$$

a. Outline **two** characteristics of a reversible reaction in a state of dynamic equilibrium. [2]

b. Deduce the equilibrium constant expression, K_c, for the reaction. [1]

c. Predict, with a reason, how each of the following changes affects the position of equilibrium. [2]

The volume of the container is increased.

Ammonia is removed from the equilibrium mixture.

d.i. Define the term *activation energy*, E_a. [1]

d.ii. Ammonia is manufactured by the Haber process in which iron is used as a catalyst. Explain the effect of a catalyst on the rate of reaction. [2]

d.iii. Sketch the Maxwell–Boltzmann energy distribution curve for a reaction, labelling both axes and showing the activation energy with and without a catalyst. [2]

e. Typical conditions used in the Haber process are 500 °C and 200 atm, resulting in approximately 15% yield of ammonia. [3]

(i) Explain why a temperature lower than 500 °C is **not** used.

(ii) Outline why a pressure higher than 200 atm is **not** often used.

f.i. Define the term *base* according to the Lewis theory. [1]

f.ii. Define the term *weak base* according to the Brønsted-Lowry theory. [1]

f.iii. Deduce the formulas of conjugate acid-base pairs in the reaction below. [2]

$$CH_3NH_2(aq) + H_2O(l) \rightleftharpoons CH_3NH_3^+(aq) + OH^-(aq)$$

Acid	Conjugate base
.....	.....
.....	.....

f.iv. Outline an experiment and its results which could be used to distinguish between a strong base and a weak base. [3]

Across period 3, elements increase in atomic number, decrease in atomic radius and increase in electronegativity.

a. Define the term *electronegativity*. [1]

b. Explain why the atomic radius of elements decreases across the period. [2]

c.i. State the equations for the reactions of sodium oxide with water and phosphorus(V) oxide with water. [2]

c.ii. Suggest the pH of the solutions formed in part (c) (i). [2]

d. Describe **three** tests that can be carried out in the laboratory, and the expected results, to distinguish between $0.10\ \text{mol}\,\text{dm}^{-3}\ HCl(aq)$ and $0.10\ \text{mol}\,\text{dm}^{-3}\ CH_3COOH(aq)$. [3]

e. Explain whether BF_3 can act as a Brønsted-Lowry acid, a Lewis acid or both. [2]

f.i. Describe the bonding and structure of sodium chloride. [2]

f.ii. State the formula of the compounds formed between the elements below. [2]

Sodium and sulfur:

Magnesium and phosphorus:

g. Covalent bonds form when phosphorus reacts with chlorine to form PCl_3. Deduce the Lewis (electron dot) structure, the shape and bond angle in PCl_3 and explain why the molecule is polar. [4]

Lewis (electron dot) structure:

Name of shape:

Bond angle:

Explanation of polarity of molecule: