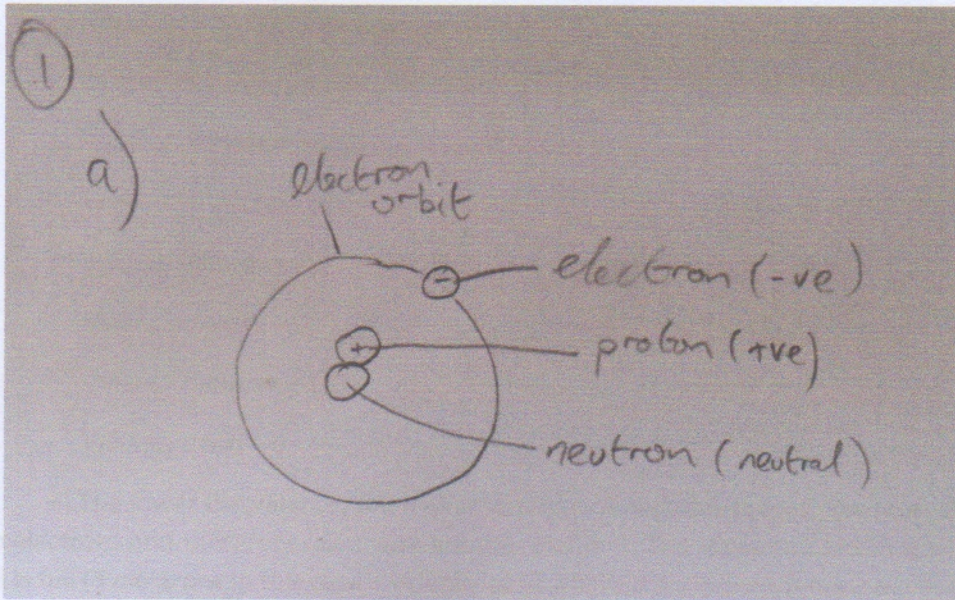




1. B) 1. An electron can revolve around the nucleus in certain fixed orbits of definite energy without emission of any radiant energy. Such orbits are called stationary orbits
2. An electron can make a transition from a stationary orbit of higher energy to a stationary orbit of lower energy and in so doing emits a single photon with a characteristic wavelength.
3. Only those orbits are allowed for which the angular momentum of the orbit is an integer multiple of $h/2\pi$ where h is Planck's constant.

c) when energy is imparted to an atom, the electron rises in energy levels. When it is lost, the energy is emitted as electromagnetic radiation at a set of wavelengths specific to the element, which can be detected.

d) practical uses for this phenomenon include spectroscopic analysis, allowing for the identification of elemental makeup of a compound, or burning specific materials in order to obtain specific effects in pyrotechnics.

2. A) 8 groups in the periodic table:

Hydrogen

Poor metals

Alkali metals

Nonmetals

Alkali earth metals

Noble gases

Transition metals

Rare earth metals

b) Mass number A is the combined number of protons and neutrons in a single atom of an element, where the atomic number Z is the number of protons within the same atom.

c) Nitrogen – 5 electrons in outer shell

Oxygen – 6 electrons in outer shell

Fluorine – 7 electrons in outer shell

Neon – 8 electrons in outer shell

d) Valency Nitrogen – 3

Valency oxygen – 2

Valency fluorine – 1

Valency neon – 0

e) The lower the valency, the higher strength of negative charge, the more likely the atom to strip electrons and therefore react with another element. The exception to this is when the outer shell is full (8 electrons in this case – valency of 0) where the element is non-reactive as it is not trying to receive or donate electrons.

f) The elements most used in explosives and pyrotechnics are hydrogen, carbon, oxygen and nitrogen. Many other elements are used in pyrotechnics to create specific effects.

3. A) Stability in explosives chemistry is the capability of an explosive material to resist degradation over time in storage conditions.

b) Boltzmann Energy Distribution is the spread of molecular velocities in a material at specific a temperature.

c) Activation energy is the minimum quantity of energy required to initiate a specific reaction within a chemical process.

d) NC is less stable than RDX as it requires less energy input in order to react (86kJ mol^{-1} rather than 199kJ mol^{-1}).

e) stabilisers are used to extend the life of NC propellants by stopping auto-catalysation during storage. Whilst decomposition cannot be stopped, it can be slowed.

f) rule of thumb for rate of chemical reaction changing with temperature, increase of 10° halves the service life. 30° increase equates to $1/8$ service life, which means the remaining life on the charges stored at 50° is 1.25 years.

g) possible hazards if left beyond this time are increased sensitivity or decomposition products increasing the heat further, to the point of self-ignition.

4. a) The overall enthalpy change that accompanies a reaction is independent of the route taken provided the initial and final states are the same.

4

3

4

1

15
=

1

3

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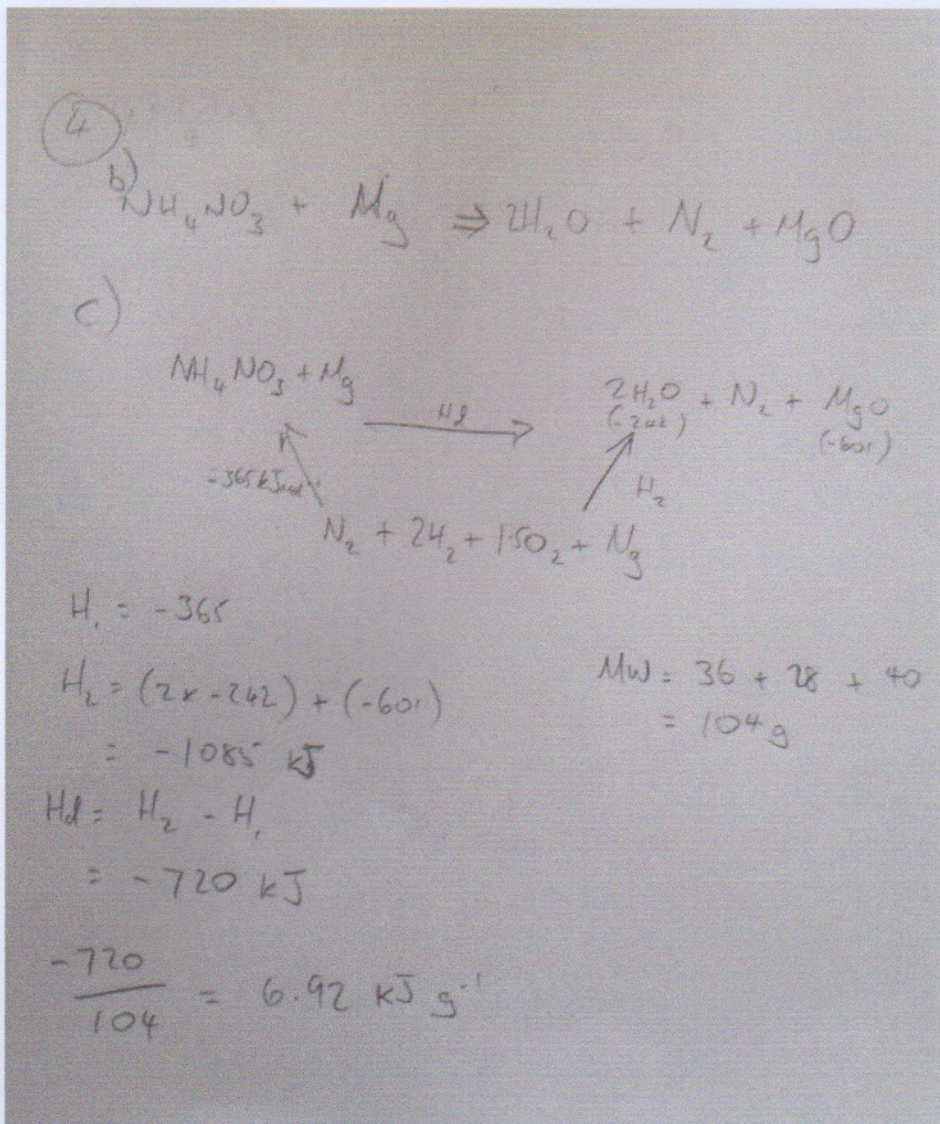
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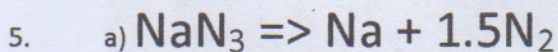
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16
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1



d) this shows the heat of reaction in this case is higher than that of TNT



b) MW $\text{NaN}_3 = 65 \text{ g}$. $130 \text{ g} = 2 \text{ mol NaN}_3$

3 mol of N_2 gas produced. MW of N is 14 g .

$6 \times 14 = 84 \text{ g}$ gas produced

c) at STP, $1 \text{ mol gas} = 22.7 \text{ l}$

$3 \times 22.7 = 68.1 \text{ l}$ of gas produced

- b) purification and mechanical preparation of raw cotton or cotton linters;
- nitration of the cotton with nitric and sulphuric acid to produce nitrocellulose;
- pulping;
- washing to free the nitrocellulose from acids and low nitrates;
- peaching the nitrocellulose to free it from unstable polymers;

(5d)

$$\frac{V_1}{T_1} = \frac{V_2}{T_2}$$

$$V_1 = 68.1 \text{ L}$$

$$T_1 = 273 \text{ K}$$

$$T_2 = 373 \text{ K}$$

$$\frac{V_1 \times T_2}{T_1} = V_2$$

$$\frac{68.1 \times 373}{273} = V_2$$

$$V_2 = 93.05 \text{ L @ } 100^\circ\text{C}$$

(2)

$$e) \frac{P_1}{T_1} = \frac{P_2}{T_2}$$

$$P_1 = 100 \text{ kPa (STP)}$$

$$T_1 = 273 \text{ K (STP)}$$

$$T_2 = 373 \text{ K}$$

$$\frac{P_1 \times T_2}{T_1} = P_2$$

$$P_2 = \frac{100 \times 373}{273}$$

$$= 136.63 \text{ kPa}$$

(2)

$$f) PV = nRT = \text{work done} = \frac{1}{2}mv^2$$

$$PV = \frac{1}{2}mv^2$$

$$\frac{PV}{\frac{1}{2}m} = v^2$$

$$93.05 \text{ L} = 0.093 \text{ m}^3$$

$$\sqrt{\frac{136.63 \times 0.093}{0.5 \times 0.5}} = v$$

$$= 225.45 \text{ ms}^{-1}$$

(2)

g) this velocity cannot be obtained in practice as other energy losses (friction, air resistance, heat loss to the barrel, etc.) are not taken into account in the calculations

(2)

(14)

6. a) Nitrocellulose should more strictly be named cellulose nitrate as the molecule has an NO_2 group attached to it.

(2)

- b) purification and mechanical preparation of raw cotton or cotton linters;
- nitration of the cotton with nitric and sulphuric acid to produce nitrocellulose;
- pulping;
- washing to free the nitrocellulose from acids and low nitrates;
- poaching the nitrocellulose to free it from unstable isomers;

- wringing;
- mixing of the nitrocellulose with ether and alcohol and pressing to form a colloid;
- granulating;
- drying and blending

c) nitrating with just nitric acid is inefficient. The addition of sulphuric acid to the process introduces a more hydrophilic nitronium ion, which soaks up additional water in the process. This allows the process to become more aggressive and faster, at a lower activation energy.

d) poaching nitrocellulose is boiling the material for an extended time in order to intentionally decompose unwanted unstable byproducts of the process.

e) Low nitrogen nitrocellulose is 12% nitrogen or less, high nitrogen NC is 12%-14%.

f) single base propellant is just NC. Cheap, smokeless, efficient, easy to manufacture. Requires high pressure to burn effectively, so suitable for pistols other small arms)

double base propellant is NC with Nitroglycerine added. Increased sensitiveness, higher energy propellant, more suitable for use in shotguns, mortars and other lower pressure systems. However higher energy means increased wear on barrel.

Triple base propellant is NC, NG and added Nitroguanidine. This addition burns at a much lower temperature, and gives out lots of gas. Suitable for very low pressure systems as the burning at the lower temp mitigates against barrel erosion

g) increased sensitiveness and barrel erosion

h) smokeless, cheap, efficient, easy to ignite and easy to manufacture

7. a) sensitivity – how easily an explosive detonates in its design mode. Sensitiveness – how easily an explosive functions under accident conditions

b)

c) AN – main explosive component

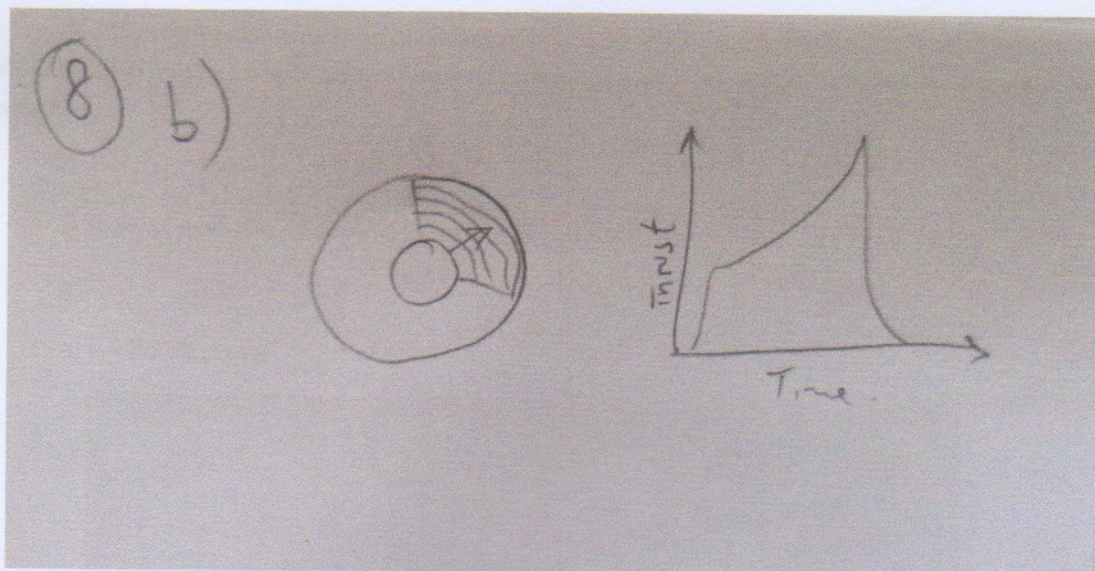
glass microballoons – create hotspots by adiabatic compression of air within the explosive. Sensitises and increases heat of explosion

d)

e)

8. a) pressure time profile of a rocket propellant can be controlled through grain geometry, chamber geometry/design and chemistry (material used as propellant)

a) the dyes are heated by the oxidising agent and boiled off to produce coloured smoke



c) $r = \beta P^\alpha$ where :

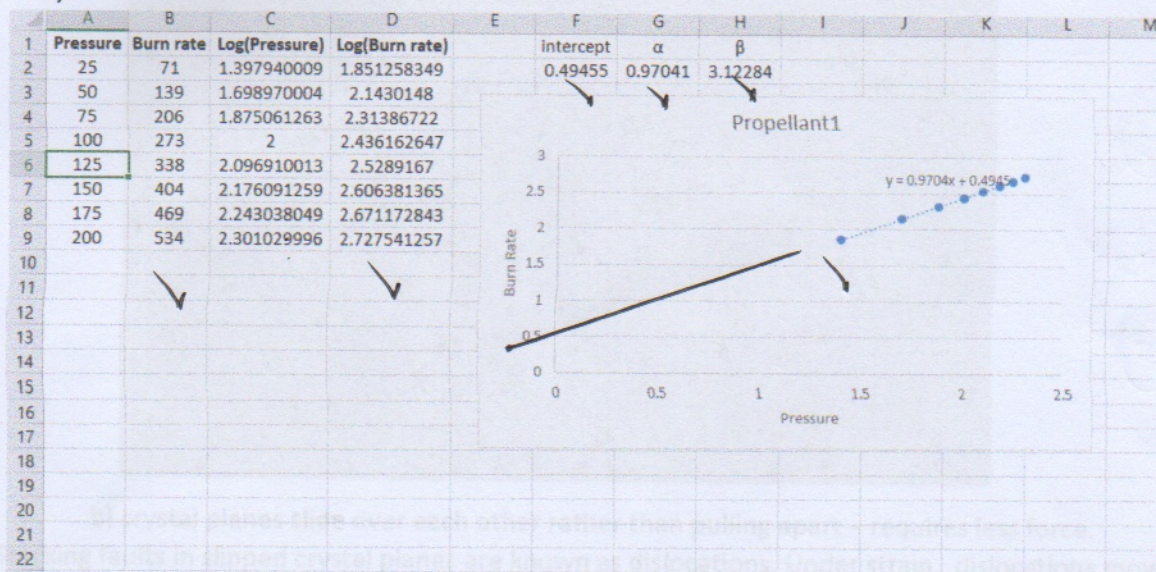
r = burning rate [mm s^{-1}]

β = burning rate coefficient (specific to a given propellant)

P = pressure [MPa]

α = pressure index

d)



9. a) the dyes are heated by the oxidising agent and boiled off to produce coloured smokes

b)

c)

d) rate of change of smoke production could be affected by the heat of the reaction, the materials used in the composition, the percentages of each reactant, the design of the delivery mechanism

(3)

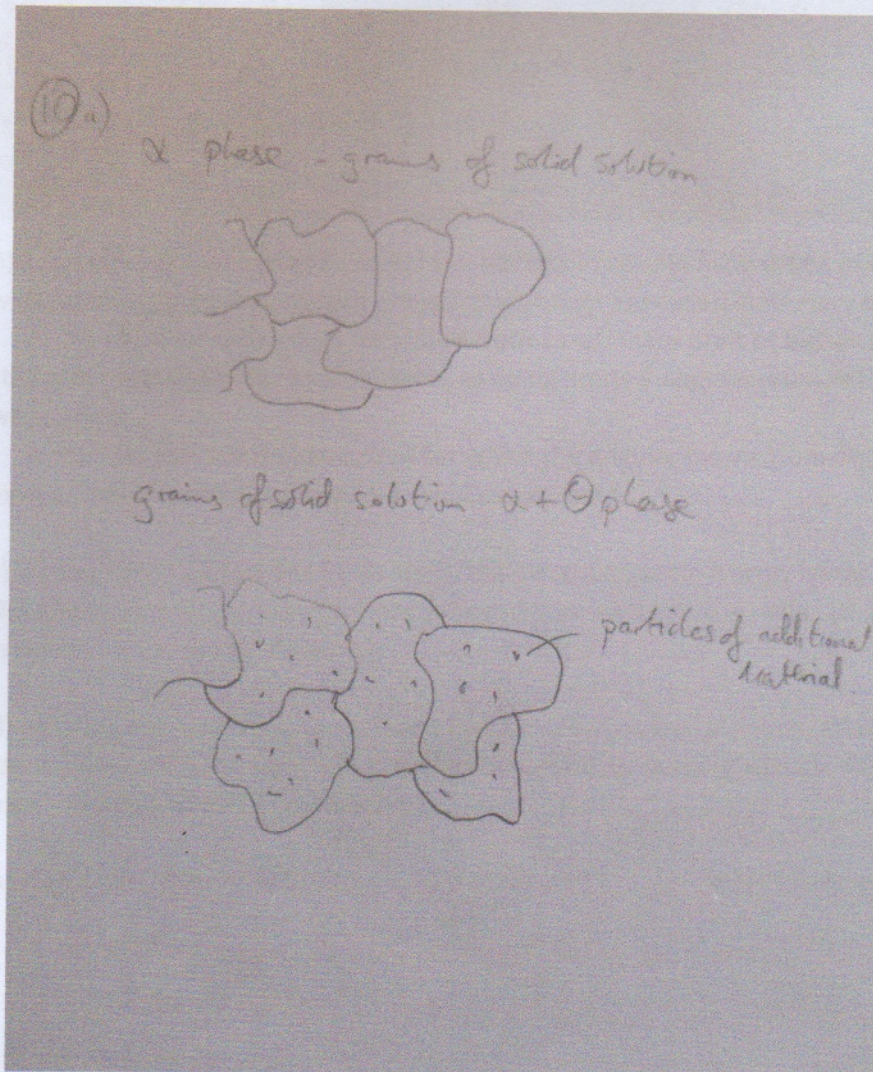
e)

f) the gas in the smoke signal is to stay visible and localised as long as possible

(7)

g)

10. a) L – liquid phase



(5)

b) crystal planes slide over each other rather than pulling apart – requires less force. Stacking faults in slipped crystal planes are known as dislocations. Under strain, dislocations move one row at a time in a rucking effect (like a carpet).

(4)

(9)