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| C:\Users\staff\Desktop\LOGO.jpg | GIET MAIN CAMPUS AUTONOMOUS GUNUPUR – 765022 |
| B. Tech Degree Examinations, April / May – 2021(FOURTH Semester) **BCHPC6030 - FUEL AND ENERGY TECHNOLOGY**(Branch Name) |
| Time: 3 hrs Maximum: 100 Marks |

**Answer ALL Questions**

**The figures in the right hand margin indicate marks.**

**PART – A: (Multiple Choice Questions) (2 x 10 = 20 Marks)**

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| Q.1. Answer ***ALL*** questions | [CO#] | [PO#] |
| a. | Calorific Value of coal can be determined from the \_\_\_\_\_\_\_\_of complete combustion at 298K and 1 atm. pressure. | 1 |  |
|  | 1. **heat of formation of products**
 | 1. Heat of reaction of reactants
 |  |  |
|  | 1. Latent heat of vaporization
 | 1. Latent heat of by products
 |  |  |
| b. | Nitrogen content of almost all coals is in the range of \_\_\_\_\_ wt % | 1 |  |
|  | 1. 20 - 30%
 | 1. 10- 95 %
 |  |  |
|  | (iii) **1-2 %**  | (iv) 10- 20%  |  |  |
| c. | Oil shale is an organic-rich [fine-grained](https://en.wikipedia.org/wiki/Granularity%22%20%5Co%20%22Granularity) [sedimentary rock](https://en.wikipedia.org/wiki/Sedimentary_rock%22%20%5Co%20%22) containing \_\_\_\_\_\_\_\_\_\_\_  from which liquid [hydrocarbons](https://en.wikipedia.org/wiki/Hydrocarbon%22%20%5Co%20%22Hydrocarbon) can be produced, called [shale oil](https://en.wikipedia.org/wiki/Shale_oil%22%20%5Co%20%22Shale%20oil). | 2 |  |
|  | 1. alkenes
 |  **(ii)[kerogen](https://en.wikipedia.org/wiki/Kerogen%22%20%5Co%20%22Kerogen)** |  |  |
|  | 1. Cyclic napthenes
 | 1. mercaptans
 |  |  |
| d. |  \_\_\_\_\_\_\_\_\_\_are cyclic saturated hydrocarbons with the general formula, like olefins, of CnH2n,also known as cyclo-alkanes. | 2 |  |
|  | 1. Alkanes
 |  (ii)**Naphthenes** |  |  |
|  | 1. Paraffins
 | 1. Aromatics
 |  |  |
| e. | The compounds in crude petroleum oil are essentially hydrocarbons or substituted hydrocarbons in which the major elements are carbon at \_\_\_\_\_\_\_\_\_ and hydrogen at \_\_\_\_\_\_\_\_\_ respectively with traces of non hydrocarbon element | 2 |  |
|  |  (i) 10%–14% and 85%–90% |  (ii) 2 %-3 % and 97% -98% |  |  |
|  | 1. **85%–90% and 10%–14%**
 | 1. 0.5% - 1% and 99.5% - 99%
 |  |  |
| f. | Which of the following compound is present in natural gas? | 3 |  |
|  | 1. Fumic acid
 | 1. **Methane**
 |  |  |
|  | 1. Benzoic acid
 | 1. Sulphuric oxide
 |  |  |
| g. | In a nuclear reactor, the chain reaction is constantly managed by means of control rods which are made from a material capable of \_\_\_\_\_\_\_\_\_\_. | 4 |  |
|  | 1. Reducing pressure
 | 1. Monitoring the fusion reaction
 |  |  |
|  | 1. Fission induction
 | (iv**)absorbing neutrons** |  |  |
| h. | During nuclear reaction, When fission occurs, the release of energy drives the lighter elements or fission products and the surplus neutrons away from one another at \_\_\_\_\_\_\_\_ | 4 |  |
|  | 1. Low pressure
 |  (ii)**high velocity** |  |  |
|  | 1. Low velocity
 | 1. High temperature
 |  |  |
| i. | In nuclear reactor, the moderator is used  | 4 |  |
|  |  (i)**to reduce the energy of the neutrons** |  (ii)to remove the heat from the fuel elements |  |  |
|  | (iii)to penetrate between the fuel rods | (iv)to maintain the proper neutron balance. |  |  |
| j. | The liquid graphite reactor has a graphite block core similar to that of  | 4 |  |
|  | 1. Pressurized heavy water reactor
 |  (ii)a gas cooled reactor |  |  |
|  | 1. Water reactor
 | 1. Radiation reactor
 |  |  |

**PART – B: (Short Answer Questions) (2 x 10 = 20 Marks)**

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| --- | --- | --- |
| Q.2. Answer ***ALL*** questions | [CO#] | [PO#] |
| a. | What is proximate analysis of coal?This analysis of coal gives good indication about heating and burning properties of coal. The test gives the composition of coal in respect of moisture, volatile matter, ash and fixed carbon. T | 1 |  |
| b. | What is hard coal?Anthracite is also called “hard coal,” anthracite forms from bituminous coal when great pressures developed in folded rock strata during the creation of mountain ranges | 1 |  |
| c. | What is coal petrography?Coal petrography is a microscopic technique used to determine a coal’s rank (degree of coalification) and type | 1 |  |
| d. | Define smoke point.The smoke point is determined as the height of the flame (in millimetres) produced by this oil in the wick of a stove or a lamp without forming any smoke. The greater the smoke point, the better the burning quality.  | 2 |  |
| e. | Define octane number Octane number is defined, for any Motor Spirit fuel, as the percentage of iso-octane in a mixture of iso-octane and n-heptane, which will give the same engine performance as could be achieved by the actual fuel sample. | 2 |  |
| f. | Define Destructive distillationThe process of pyrolysis conducted in a distillation apparatus to allow the volatile products to be collected. An example is tar making from pinewood slices (which are rich in terpenes), which are heated in an airless container causing the material to decompose, leaving charcoal and turpentine as by-products. | 3 |  |
| g. | What is the composition of coke oven gas?The classic composition of coke gas: hydrogen (H2 - 51%), methane (CH4 - 34%), carbon monoxide (CO - 10%), ethylene (C2H4 - 5%). The composition may also include benzene (C6H6), ammonia (NH3), hydrogen sulfide (H2S) and other components. | 3 |  |
| h. | What is blast furnace gas?Blast furnace gas (BF gas)  is a byproduct gas produced during the production of hot metal (liquid iron) in a blast furnace, where iron ore is reduced with coke to produce hot metal. The blast furnace gas which comes out from the top of the blast furnace is at a high pressure (usually 1.5 atm to 2.5 atm in modern blast furnaces) and normally at a temperature of around 100 deg C to 150 deg C. | 3 |  |
| i. | What is the advantages of nuclear fuel?Unlike [fossil fuels](https://energyeducation.ca/encyclopedia/Fossil_fuel%22%20%5Co%20%22Fossil%20fuel), using nuclear fuels to produce energy does not directly produce [carbon dioxide](https://energyeducation.ca/encyclopedia/Carbon_dioxide%22%20%5Co%20%22Carbon%20dioxide) or [sulfur dioxide](https://energyeducation.ca/encyclopedia/SOx%22%20%5Co%20%22SOx)While nuclear fuel is not renewable, it is [sustainable](https://energyeducation.ca/encyclopedia/Sustainable%22%20%5Co%20%22Sustainable) since there is so much of it. It will run out eventually, but not for centuries. | 4 |  |
| j. | Define fuel in a nuclear power plantThe fuel used in a nuclear power plant contains fissile atoms whose energy is extracted by fission. Uranium-235 is more than often used as the fuel. Pressed into pellets, the fuel is inserted into leak tight cladding called “fuel rods”.  | 4 |  |

**PART – C: (Long Answer Questions) (15 x 4 = 60 Marks)**

|  |  |  |  |
| --- | --- | --- | --- |
| Answer ***ALL*** questions | Marks | [CO#] | [PO#] |
| 3. a. | What are the types of coal? There are four major types (or “ranks”) of coal. Rank refers to steps in a slow, natural process called “coalification,” during which buried plant matter changes into an ever denser, drier, more carbon-rich, and harder material. The four ranks are:* ****Anthracite****: The highest rank of coal. It is a hard, brittle, and black lustrous coal, often referred to as hard coal, containing a high percentage of fixed carbon and a low percentage of volatile matter.
* ****Bituminous****: Bituminous coal is a middle rank coal between subbituminous and anthracite. Bituminous coal usually has a high heating (Btu) value and is used in electricity generation and steel making in the United States. Bituminous coal is blocky and appears shiny and smooth when you first see it, but look closer and you might see it has thin, alternating, shiny and dull layers.
* ****Subbituminous****: Sub bituminous coal is black in color and is mainly dull (not shiny). Sub bituminous coal has low-to-moderate heating values and is mainly used in electricity generation.
* ****Lignite****: Lignite coal, aka brown coal, is the lowest grade coal with the least concentration of carbon. Lignite has a low heating value and a high moisture content and is mainly used in electricity generation.

The precursor to coal is peat. Peat is a soft, organic material consisting of partly decayed plant and mineral matter. When peat is placed under high pressure and heat, it undergoes physical and chemical changes (coalification) to become coal. |  | 1 |  |
| b. | What is carbonisation and write the objective of coal carbonisation CARBONISATION – the destructive heating of coal in the absence of air, with the production of COKE and the evolution of VOLATILE PRODUCTS.* To produce Carbon-rich product that will provide heat for the Blast Furnace – by removal of Volatile Matter i.e. Devolatilisation
* To produce Carbon Monoxide for the reduction of the Iron Ore.
 |  | 1 |  |
|  | (OR) |  |  |  |
| c. | Write the significance of coal composition.Coal is a mineral in which the chemical element of **carbon** is prevalent. Carbon content (the so-called **coalification**) depends foremost on the time during which the conversion from plant matter to the final mineral took place. The older the coal, the higher the carbon percentage and the less apparent the original vegetable component, i.e. the fossil, remains of plant tissues, resin, etc. And, in particular, such coal is of higher quality and is in greater demand. However, besides that coalification and representation of impurities is dependent on other circumstances, in particular on species composition of plants from which the coal was formed, on the character of the deposit, geological history thereof, etc.Other components represented to various extents according to the types of coal are the following:* water
* clay rocks
* silicate rocks
* sulphur compounds

 The rank of coalification and content of other components is important for the possibility of **coal utilization**. Coal with high carbon content and low impurities serves for coking, chemical industry etc. Raw material of lesser quality is used for combustion and production of electricity in power-plants. |  | 1 |  |
| d. | **What is coke in real terms?**Coke is **solid carbon residue** produced from low-ash, low-sulphur hard coal, from which the volatile components are removed in ovens with limited oxygen inlet and temperatures around 1000 °C. During this process bituminous coal tar, ammoniac, light oils and coal-gas are produced. It has an outstanding **calorific value of 29,6 MJ/kg**, its other properties are also important in metallurgy, in particular **high carbon content and little residue of combustion**. Owing to its high calorific value and favourable combustion products (in fact only carbon dioxide is produced during burning), and low dust formation, coke is the only fuel allowed in certain city centres. Originally, in metal production in the rest of the world as well as in the Ostrava region charcoal was used as the source of heat and a reducing agent. It started being replaced by coal coke in the first half of the 19th century. It is notable that coke is produced also in the processing of oil (the so-called **petroleum coke**), however, due to its high percentage of debris it is not suitable for metal production.  |  | 1 |  |
|  |  |  |  |  |
| 4. a. | Explain the Naptha reforming process.Desulfurised naphtha (90°C–140°C) is catalytically converted to high octane gaso line by the reaction of a platinum (now platinum–rhenium) catalyst in a reactor in a hydrogen environment. This type of treatment is also known as platforming. The major reactions involved during platforming are dehydrogenation, isomerisation, and dehydrocyclisation along with a small amount of hydrocracking and hydrogenation reactions. Desulfurised naphtha and hydrogen are mixed and preheated by heat exchangers followed by heating in a tube-still furnace to raise the temperature of the vapour mixture to around 500°C. The reaction temperature is 470°C at the start of the run (SOR), i.e., when the catalyst is fresh or regenerated. A traditional reformer catalyst contains 0.3–0.35% wt of platinum. Since, during the reaction, coke formation takes place over the surface of the catalyst, the reactivity of the catalyst comes down and the temperature has to be raised to maintain the uniform reactivity. When the catalyst is used for about a year, the temperature has to be maintained near 520°C. The temperature is not raised further to avoid permanent damage to the catalyst. However, deactivation due to coke laydown is temporary and can be removed by burning the coke in the presence of air during regeneration. However, damage due to high temperatures above 600°C is permanent because of the sintering of the catalyst; hence the temperature at the end of the run (EOR) is never allowed to increase above 520°C. Traces of sulfur, nitrogen, and oxygen present in the feed naphtha permanently deactivate the catalyst and that is why naphtha pretreatment is carried out before reforming. In order to reduce coke formation, it is essential to maintain hydrogen circulation at a desired partial pressure. Usually a minimum of 5 mol of hydrogen per mole of feed naphtha must be maintained during the reaction. The total pressure of the system is about 25–30 kg/cm2. Usually, three reactors in a series are employed while regeneration is carried out for all the reactors after complete shutdown of the unit. Alternatively, four reactors may be employed while three reactors, in fact, are in service and the fourth reactor (swing reactor) is taken out for regeneration. This unit does not require complete shut down and hence production is not affected. Three reactors are used in this fl ow sheet, the first two are spherical in shape while the last one is cylindrical. The catalyst is loaded and distributed in these reactors in the ratio of 15:35:60 by percent weight of the total weight of the catalyst loaded, respectively. Since the overall reactions are endothermic in nature, the product temperature falls while exiting from a reactor and is reheated by the intermediate furnace before it enters the second and third reactor. Finally, the product mixture is cooled and separated from hydrogen by fl ashing in a vessel at a temperature of 50°C. Hydrogen from this vessel is partly recycled back to the reactors and a part is sent to other hydrogenconsuming units in the refinery. The product from the bottom of the separator vessel is sent to a plated column to separate the butane and lighter hydrocarbons from the final product, known as the debutanised reformate, which is cooled before storage. |  | 2 |  |
| b. | Draw single stage and two stage electrical desalting process . IMG_256 |  | 2 |  |
|  | (OR) |  |  |  |
| c. | Explain crude atmospheric distillation process After desalting process, the crude oil is heated in heat exchangers or reboilers (preheating of crude oil). Of course, preheating is not sufficient, since the oil must be partially evaporated to the extent that all products except atmospheric residues must be in the vapor phase when the oil enters the atmospheric column. Thus, the furnace is required to raise the temperature between 330 and 385°C depending on the components of oil. The partially evaporated crude oil is transferred to the flash zone column located at a point below the distillation column and above what is called the stripping section. The main distillation column is generally up to 50 m with a 30–50 valve. The size of the column is determined by the number of plates and the amount of steam. Besides, the amount of steam is determined by the content of crude oil in volatile elements or compounds. As a result, the rising steam in huge amounts and at top flow rates, requires a large diameter column above the flash zone. At the bottom of the section, water vapor is injected into the column to remove the atmospheric residue of any light hydrocarbon and reduce the partial pressure of hydrocarbon vapors in the flash zone . This causes the true boiling point of hydrocarbons to decrease and causing more hydrocarbons to boil and raise the column to eventually thicken and removed as lateral flows. As hot vapors grow from the flash zone, they ascend into the column through the plates to the upper zone of the column. A portion part of the light fraction of naphtha or gasoline returns to the column in the form of reflux. This reflux allows controlling the quality of the distillate and the pressure in the column. The main products of atmospheric petroleum distillation are Gas, Gasoline,kerosene, diesel oil , atmospheric residue.  |  | 2 |  |
| d. | Explain mild hydrocracking process The term “mild hydrocracking” implies hydrocracking at mild operating conditions. It is carried out mostly for producing middle distillates and fuel oils from vacuum distillates, catalytic dewaxing for lube base stock at a pressure below 10 MPa and at a temperature range varying from 350°C to 450°C. Since pressure is low compared to hydrocracking reactors, mild hydrocracking can be carried out in the traditional hydrotreatment reactors. Conversion of vacuum distillates may not exceed 50%. |  | 2 |  |
|  |  |  |  |  |
| 5. a. | Write the significance of direct coal liquefaction process and indirect coal liquefcation process. Direct coal liquefaction involves contacting coal directly with a catalyst at elevated temperatures and pressures with added hydrogen (H2), in the presence of a solvent to form a raw liquid product which is further refined into product liquid fuels. DCL is termed direct because the coal is transformed into liquid without first being gasified to form [syngas](https://www.netl.doe.gov/research/coal/energy-systems/gasification/gasifipedia/syngas-composition) (which can then in turn be transformed into liquid products). The latter two-step approach, i.e. the coal to syngas to liquids route is termed [indirect coal liquefaction](https://www.netl.doe.gov/research/coal/energy-systems/gasification/gasifipedia/indirect-liquefaction) (ICL). Therefore, the DCL process is, in principle, the simpler and more efficient of the two processes. It does, however, require an external source of H2, which may have to be provided by gasifying additional coal feed, biomass and/or the heavy residue produced from the DCL reactor. The DCL process results in a relatively wide hydrocarbon product range consisting of a variety of molecular weights and forms, with aromatics dominating. Accordingly, the product requires substantial upgrading to yield acceptable transportation fuels |  | 3 |  |
| b. | Write the chemistry involved in the Fischer-Tropsch processThe Fischer-Tropsch process is a catalytic chemical reaction in which carbon monoxide (CO) and hydrogen (H2) in the syngas are converted into hydrocarbons of various molecular weights according to the following equation:(2n+1) H2 +  n CO  → Cn H(2n+2)  +  n H2OWhere n is an integer. Thus, for n=1, the reaction represents the formation of methane, which in most CTL or GTL applications is considered an undesirable byproduct. The Fischer-Tropsch process conditions are usually chosen to maximize the formation of higher molecular weight hydrocarbon liquid fuels which are higher value products. There are other side reactions taking place in the process, among which the water-gas-shift reactionCO + H2O → H2  +  CO2is predominant. Depending on the catalyst, temperature, and type of process employed, hydrocarbons ranging from methane to higher molecular paraffins and olefins can be obtained. Small amounts of low molecular weight oxygenates (e.g., alcohol and organic acids) are also formed. The Fischer-Tropsch synthesis reaction, in theory, is a condensation polymerization reaction of CO. Its products obey a well-defined molecular weight distribution according to a relationship known as Shultz-Flory distribution. |  | 3 |  |
|  | (OR) |  |  |  |
| c. | Discuss the process of producer gas.Producer gas is a combustible gas manufactured by blowing a mixture of steam and air upwards through a bed of hot coke, or coal, such that the fuel is completely gasified. The gas obtained from coke consists mainly of a mixture of carbon monoxide and hydrogen with the nitrogen from the blast of air. When coal is used the gas will contain, in addition, tar and the gases liberated during the carbonization of the coal in the fuel bed.The process is carried out usually by charging the fuel by gravity from a hopper into a vertical, cylindrical, steel chamber, which is either lined with fire bricks, or it has an annular water-jacket from which steam required for gasification can be raised by heat transmitted from the fuel bed. The fuel bed is supported at the bottom by a grate/distributor, through which is introduced the blast, made by adding steam to the air supply such that it is saturated at a temperature of about 50°C.A layer of ash is maintained at the bottom of the fuel bed; it serves to protect the grate and to distribute and preheat the blast. Immediately above the ash zone is a narrow combustion zone in which oxygen in the air reacts with carbon in the fuel to form carbon dioxide, thereby generating the heat to sustain the subsequent gasification reactions. The hot gases and steam move upwards into the reduction zone where endothermic reactions occur between carbon and carbon dioxide, and between carbon and steam to produce carbon monoxide and hydrogen. At the top of the bed the incoming fuel is dried and carbonized. Most of the sulfur in the coal appears as hydrogen sulfide in the product gas.The hot gases leaving the producer are quenched and washed with water to remove dust and tar and, if required, purified to remove hydrogen sulfide. A typical producer gas obtained from coke contains 27% carbon monoxide, 12% hydrogen, 0.5% methane, 5% carbon dioxide and 55% nitrogen, by volume. It has a heating value of about 5,000 kJ/m3. When coal is used as fuel the producer gas contains about 3% methane and 0.5% higher hydrocarbons. |  | 3 |  |
| d. | What are the different forms of water gas and its useThere are different types of water gas. The composition of the resulting gas depends on the process used to make it:* ****Water gas shift reaction gas****: This is the name given to water gas made using the water-gas shift reaction to obtain pure hydrogen (or at least enriched hydrogen). The carbon monoxide from the initial reaction is reacted with water to remove carbon dioxide, leaving only the hydrogen gas.
* ****Semi-water gas****: Semi-water gas is a mixture of water gas and producer gas. Producer gas is the name of fuel gas derived from coal or coke, as opposed to natural gas. Semi-water gas is made by collecting the gas produced when steam is alternated with air to burn coke to maintain a high enough temperature to sustain the water gas reaction.
* ****Carburetted water gas****: Carburetted water gas is produced to enhance the energy value of water gas, which is ordinarily lower than that of coal gas. Water gas is carburetted by passing it through a heated retort which has been sprayed with oil.

Uses of Water GasWater gas used in the synthesis of some industrial processes:* To remove carbon dioxide from fuel cells.
* Reacted with producer gas to make fuel gas.
* It is used in the Fischer-Tropsch process.
* It is used to obtain pure hydrogen to synthesize ammonia.
 |  | 3 |  |
|  |  |  |  |  |
| 6. a. | Discuss pressurized water reactorThe pressurized water reactor overcomes the problem of a slightly radioactive steam circuit by having an intermediate heat exchanger to separate the reactor coolant circuit from the turbine steam circuit. Steam is generated in this steam generator and is sent to the turbine as saturated steam under conditions similar to those in the boiling water reactor. The reactor coolant circuit is maintained at high pressure to prevent any boiling in the reactor and operates at a slightly higher temperature than the BWR to promote heat transfer to the secondary steam circuit. Because no boiling occurs in the reactor core, it is more compact and does not require channels. The fuel rods of the individual elements form a continuous vertical matrix in the core. This is flooded with an upward flow of circulating light water which serves as coolant and moderator. |  | 4 |  |
| b. | What is the purpose of coolant and steam generator in nuclear reactor The energy released as heat during the fission of uranium-235 nuclei must be transferred from the reactor core to the systems designed to transform heat into electricity, i.e. the turbine and alternator. This role is guaranteed by the coolant, the fluid used to remove the heat generated by the nuclear fuel. The coolant can be water, a liquid metal (sodium or lead) or a gas (carbon dioxide or helium). The coolant is also used to maintain the fuel temperature at its nominal temperature that is compatible with the resistance of the materials.A heat exchanger is designed to transfer thermal power from one system to another. In the case of pressurised water reactors (PWRs), for instance, the primary coolant is water which exits the reactor core at a high temperature of about 330°C and is kept a high pressure of about 150 bar to prevent it from transforming into steam. This water then flows through a steam generator that is used to transfer the thermal power between the primary and secondary systems. They are designed so that the water in the secondary system boils and generates steam. When the steam expands, it drives a turbine that is coupled to an alternator which produces electricity. This system is also known as a power conversion system; thermal energy is converted into mechanical and then electrical energy. A third system is designed to cool and then condense steam. In the case of sodium-cooled fast reactors (SFRs), the primary coolant is sodium, which is a liquid metal that exits the core at about 550°C. and at low pressure (several bar). The power conversion system is based on the same principle as that of a PWR: a steam generator produces steam which expands in a turbine coupled to an alternator. The key difference is an additional system interposed between the primary system containing low-pressure sodium and the water-to-steam power conversion system at high pressure. The objective of this intermediary system is to take into account the risk of interaction between sodium and water by dissociating the radiological risk in the primary system from other risks. Two heat exchangers are therefore required between the primary system and the power conversion system |  | 4 |  |
|  | (OR) |  |  |  |
| c. | Discuss gas cooled reactorThe gas cooled reactor, like the pressurized water reactor, has separate reactor coolant and steam generating circuits with an intermediate steam generator. The coolant, however, is gas, which enables higher coolant temperatures to be achieved. This enables superheated steam to be generated and a high efficiency steam circuit similar to that of a fossil fuel fired plant to be used. Due to the high temperatures and large core volume required with a gas coolant, graphite is more suitable than water as a moderator. This is installed in the form of blocks with holes to form channels into which the fuel elements are placed and through which the gas coolant flows. By changing the coolant from carbon dioxide to helium, even higher temperatures could be achieved, hence the designation high temperature reactor (HTR). This type gave the ultimate advantage of large gas cooled reactors, which have a cycle efficiency as high as any fossil fuel fired plant. |  | 4 |  |
| d. | Discuss nuclear reactor principlesSome heavy elements, such as uranium-235, can be induced to fission by adding a neutron to their nuclei. When fission occurs, the resultant lighter elements do not require as many neutrons in their nuclei to maintain a stable configuration and, on average, between two and three surplus neutrons are released. These neutrons can cause further fissioning of other U-235 nuclei and so establish a chain reaction. Such a reaction can be allowed to diverge, as in an atomic bomb, or be controlled, as in a nuclear reactor. Under steady state conditions, just one neutron on average from each fission should go on to produce another fission event. When fission occurs, the release of energy drives the lighter elements or fission products and the surplus neutrons away from one another at high velocity. Most of the energy is thus transformed into kinetic energy carried by the fission products. As heavy strongly charged particles, they do not travel any significant distance and dissipate their kinetic energy in the fuel by interaction with other atoms, thus increasing the temperature of the fuel. The high energy fast neutrons, being uncharged, readily pass through the fuel and other reactor materials |  | 4 |  |

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