last name   first name   uteid   signature

constants

$R = 0.08206$ L atm/mol K

$R = 8.314$ J/mol K

$N_A = 6.022 \times 10^{23}$ /mol

$h = 6.626 \times 10^{-34}$ J·s

$c = 3.00 \times 10^8$ m/s

$g = 9.81$ m/s^2

conversions

1 atm = 760 torr

1 atm = 101325 Pa

1 atm = 1.01325 bar

1 bar = 10^5 Pa

°F = °C(1.8) + 32

K = °C + 273.15

conversions

1 in = 2.54 cm

1 ft = 12 in

1 yd = 3 ft

1 mi = 5280 ft

1 lb = 453.6 g

Single Bond Energies

	H	C	N	O
H	436			
C	413	346		
N	391	305	163	
O	463	358	201	146

all values are kJ/mol

Multiple Bond Energies (kJ/mol)

C=C 602	C=N 615	C=O 799
C≡C 835	C≡N 887	C≡O 1072
N=N 418	N=O 607	C=S 577
N≡N 945	O=O 498	

water data

$C_{s,ice} = 2.09$ J/g °C

$C_{s,water} = 4.184$ J/g °C

$C_{s,steam} = 2.03$ J/g °C

$\rho_{water} = 1.00$ g/mL

$\rho_{ice} = 0.9167$ g/mL

$\rho_{seawater} = 1.024$ g/mL

$\Delta H_{fus} = 334$ J/g

$\Delta H_{vap} = 2260$ J/g

$K_w = 1.0 \times 10^{-14}$

This exam should have exactly 25 questions. Each question is equally weighted at 4 points each. Bubble in your answer choices on the online bubblehseet provided. Your score is based on what you bubble on the bubblesheet and not what is circled on the exam.

1. Fill in the blanks: Breaking bonds is an _____ process, and making bonds is an _____ one. Thus, the ΔH values for breaking and making bonds respectively, are _____ and _____ .

• a. endothermic, exothermic, positive, negative

b. exothermic, endothermic, positive, negative

c. exothermic, endothermic, negative, positive

d. endothermic, exothermic, negative, positive

Explanation: Breaking bonds requires energy input, so it is an endothermic process, which has a positive ΔH. The opposite is true for making bonds.

---

2. Which of the following processes would have a positive value for heat flow?

a. condensation

• b. sublimation

c. deposition

d. freezing

Explanation: Sublimation is an endothermic process, converting a solid directly to a gas. Such a process requires heat input which means a positive q and ΔH for the process. The other three are all exothermic.

---

3. A reaction performed in a coffee cup calorimeter makes the temperature of the water increase. Which of the following is/are true regarding this process?

I. the reaction is exothermic

II. the reaction is endothermic

III. the reaction absorbs heat

IV. the value of q_{cal} is positive

a. II and IV

• b. I and IV

c. I, III, and IV

d. II, III, and IV

e. I, II, III, and IV

Explanation: For this process, the q_{cal} is positive (it absorbed heat which is why the temperature increased. Flip the sign to get into the perspective of the reaction system. That means that the reaction is exothermic and releases heat. Only I and IV are correct.

---

4. Consider the following heat capacities (all in J/g °C) for various substances:

$C_{\text{s,chromium}} = 0.449$　　　　　　$C_{\text{s,titanium}} = 0.523$

$C_{\text{s,water}} = 4.184$　　　　　　　$C_{\text{s,air}} = 1.012$

Which substance will have the greatest increase in temperature upon the addition of 275 joules of heat to the same mass of each substance?

a. water

b. titanium

c. air

• d. chromium

Explanation: The greatest temperature change will be observed in the substance with the lowest specific heat capacity. This is titanium.

5. Which of the following is true regarding combustible fuels?

a. The chemical reaction absorbs heat because the reactants are lower in energy than the products.

b. The chemical reaction releases heat because the reactants are lower in energy than the products.

c. The chemical reaction absorbs heat because the products are lower in energy than the reactants.

●d. The chemical reaction releases heat because the products are lower in energy than the reactants.

e. The chemical reaction does not absorb or release heat because the products and reactants are equal in energy.

Explanation: The driving force behind burning a fuel is the fact that the chemical reaction releases heat because the products are lower in energy than the reactants.

---

6. Which of the following is the least efficient fuel based on its combustion enthalpy per gram?

a. ethanol

b. methane

●c. wood

d. propane

e. hydrogen

Explanation: Wood can only produce about 14 kJ of energy per gram, which is why its the least efficient.

---

7. When 0.328 g of a hydrocarbon fuel are combusted in a bomb calorimeter filled with 925 mL water, a temperature increase of 2.15 °C is measured. What is the ΔH of the fuel in kJ/g? The heat capacity of the calorimeter hardware is equal to 1550 J/°C.

a. −39.7 kJ/g

●b. −35.5 kJ/g

c. +48.4 kJ/g

d. +55.1 kJ/g

e. −52.9 kJ/g

f. −45.2 kJ/g

Explanation: bomb calorimetry: $\Delta H \approx -q_{cal}$

$q_{cal} = mC\Delta T + C\Delta T$

$11653 = (925)(4.184)(2.15) + (1550)(2.15)$

Flip the sign to get into the system: -11653 J

Convert to kJ and divide by mass:

-11.653 kJ/0.328 g = -35.5 kJ/g

---

8. Methane, ethane, propane, and butane are all examples of refinery gases. Based on the fact that these gases are the shortest carbon chains, where would you find these in a distillation tower?

●a. the top

b. the middle

c. equally dispersed throughout the distillation tower

d. the bottom

Explanation: Light chains remain at the higher portions of the distillation tower.

9. This is the corrected version of this question. All students received credit for this due to two typos. A beaker contains 288 g of methanol at 28.0 °C. What is the final temperature of methanol if it is cooled and loses 6.41 kJ of heat? The specific heat of methanol is 2.53 J/ g°C.

a. 21.8.° C

●b. 19.2° C

c. 8.50° C

d. 29.8 ° C

e. 16.4° C

Explanation: Use the formula: $q = mC_s\Delta T$

$-6410\,\text{J} = (288\,\text{g})(2.53\,\text{J/g}°\,\text{C})(T_f - 28°\,\text{C})$

$T_f = 19.2\,°\text{C}$

---

10. A simple dissolution reaction is performed in a coffee cup calorimeter. When 5.12 g of a soluble ionic salt is dissolved into 180 mL water, the temperature decreases by 9.44 °C. What is the value of ΔH for this dissolution process?

a. −5.81 kJ

b. +3.92 kJ

●c. +7.11 kJ

d. +5.81 kJ

e. −3.92 kJ

f. −7.11 kJ

Explanation: Solve for q_{cal} and then flip the sign for q_{sys}.

$q = (180\,\text{g})(4.184\,\text{J/g}°\text{C})(-9.44\,°\text{C})$

q = -7109 J = -7.11 kJ

Flip the sign to get back to the system to get +7.11 kJ.

**11.** An *open* thermodynamic system allows for the transfer of what across a system boundary?

●a. Both matter and energy

b. Matter only

c. Energy only

d. Neither matter nor energy

Explanation: An open system allows both energy and matter to flow in and out of the system boundary.

---

12. Use bond energy data (front page of exam) to determine the heat of combustion of acetylene, C_2H_2.

a. −1449 kJ/mol

●b. −1216 kJ/mol

c. −312 kJ/mol

d. −1300 kJ/mol

e. −1705 kJ/mol

**Explanation:** balance   rxn:
$C_2H_2 + 2.5O_2 \longrightarrow 2CO_2 + H_2O$
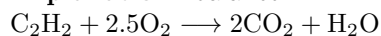
Reactant side: 2 C-H single bonds, 1 C≡C triple bond, 2.5 O=O double bonds. Product side: 4 C=O double bonds, 2 H-O single bonds.

Reactants = 2(413) + 1(835) + 2.5(498) = 2906 kJ

Products = 2(463) + 4(799) = 4122 kJ

Reactants - Products = -1216 kJ

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13. Which process of crude oil refining would most efficiently convert this linear molecule of n-octane to a branched molecule called 2,5-dimethylhexane?
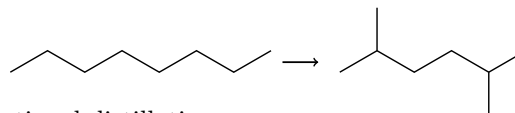
a. fractional distillation

b. thermal cracking

●c. catalytic reforming

d. catalytic cracking

Explanation: Catalytic reforming is used to break down linear chain hydrocarbons and remake them into highly branched ones.

---

14. Which of the following is an exothermic process?

a. Melting ice

b. Heating water

●c. Freezing water

d. Boiling water

Explanation: Heat is released when water is frozen to a solid. The other three absorb heat, which is endothermic.

15. I want my room temperature beverage to be cold, so I put it in the refrigerator for an hour. Then pull it out and drink it - yes, it is much colder now. I, being smart chemistry guy, know that if the beverage is the system and it "got cold" in the refrigerator, then the process must be exothermic.

a. false

●b. true

Explanation: Yes, it is true because heat was released from the beverage into the surroundings (the refrigerator) which means the process is exothermic.

---

16. Consider the following molar masses and heats of combustion for three fuel sources:

ΔH MTBE, 88.15 g/mol: 3,362.0 kJ/mol

ΔH Methane, 16.04 g/mol: 803.60 kJ/mol

ΔH Ethanol, 46.07 g/mol: 1234.7 kJ/mol

Which of these fuels is the least efficient **per gram** of fuel?

a. They are equally efficient in kJ/g.

b. Methane

c. MTBE

●d. Ethanol

Explanation: Convert the kJ/mol value into kJ/g for each and compare:

MTBE: 38 kJ/g = (3,362.0 kJ/mol)/(88.15 g/mol)

Methane: 50.1 kJ/g = (803.60 kJ/mol)/(16.04 g/mol)

Ethanol: 27 kJ/g = (1234.7 kJ/mol)/(46.07 g/mol)

---

17. The standard heat of combustion of ethanol, C_2H_5OH, is 1372 kJ/mol ethanol. How much heat (in kJ) would be liberated by completely burning a 20.0 g sample?

a. 519 kJ

b. 715 kJ

c. 469 kJ

d. 686 kJ

●e. 597 kJ

Explanation: 20.0 g ethanol / 46 g/mol = 0.43 moles of ethanol. 1372 kJ/mol × 0.43 mol = 597 kJ.

---

18. A new fuel is found to have a heat of combustion of 37 kJ/g. The density of this fuel is 0.75 g/mL. How much heat is released when 20 mL of this fuel is burned?

a. 987 kJ

b. 740 kJ

c. 612 kJ

●d. 555 kJ

e. 247 kJ

Explanation: (20 mL)(0.75 g/mL)(37 kJ/g) = 555 kJ

---

19. The first law of thermodynamics is all about the ——— .

a. generation of antimatter

●b. conservation of energy

c. dispersal of energy

d. conversion of mass to energy

Explanation: conservation of energy

---

20. When a petroleum engineer proclaims "it's time to get crackin'!" they really mean that ...

a. it's time to build bigger hydrocarbons from smaller ones

b. it's time to make the meth

●c. it's time to break larger hydrocarbons into smaller ones

d. it's time to make the hydrocarbons more branched

Explanation: cracking is breaking large hydrocarbons into smaller ones about half their original size

---

21. A calorimeter is only useful for measuring the energy content of exothermic reactions, not endothermic ones.

a. true

●b. false

Explanation: Works well for any kind of reaction, endothermic or exothermic.

---

22. Which process can turn a compound that is found lower on a distillation tower into a a more desirable compound that would be found higher on the distillation tower?

● a. catalytic cracking

b. combustion

c. fracking

d. catalytic reforming

e. calorimetry

Explanation: Catalytic cracking can provide shorter carbon chains from longer carbon chains in a specific, efficient manner.

---

23. When a hydrocarbon for a combustion engine is more branched _____ .

a. it will fail to combust

● b. it burns smoother and will have a higher octane rating

c. it will have a much higher energy of combustion

d. it will more readily pre-ignite which causes knocking

Explanation: more branching is desired (reforming) which leads to better burning fuels and higher octane ratings

---

24. The second law of thermodynamics states that the energy of the universe is always increasing.

a. true

● b. false

Explanation: No. The entropy of the universe is increasing due to spontaneous changes. First law says the energy of the universe is constant.

---

25. A sample container holding 125 grams of water is heated from 24 °C to steam at 105 °. Calculate the heat necessary for this process. (answer to nearest whole kJ)

a. 361 kJ

● b. 324 kJ

c. 41 kJ

d. 298 kJ

e. 83 kJ

Explanation: Three calculations are necessary here:

$q_1 = (125\,\text{g})(4.184\,\text{J/g})(76°\,\text{C}) = 39748\,\text{J}$

$q_2 = (125\,\text{g})(2260\,\text{J/g}) = 282500\,\text{J}$

$q_3 = (125\,\text{g})(2.03\,\text{J/g})(5°\,\text{C}) = 1268.75\,\text{J}$

$q_{\text{total}} = 39748\,\text{J} + 282500\,\text{J} + 1268.75\,\text{J} \approx 324\,\text{kJ}$

After you are finished and have all your answers circled, go to the front of the room and then use the QR code there to pull up the virtual answer page. Enter the appropriate info plus all your answers - click the SUBMIT button. Make sure you get the confirmation screen and show it to the TA or proctor. After that, turn in your exam and scratch paper. You're free to leave after that.

https://mccord.cm.utexas.edu/helium

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