______________ last name ______________ first name ______________ uteid ______________ signature

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1 H 1.008																	2 He 4.003
3 Li 6.941	4 Be 9.012											5 B 10.81	6 C 12.01	7 N 14.01	8 O 16.00	9 F 19.00	10 Ne 20.18
11 Na 22.99	12 Mg 24.31											13 Al 26.98	14 Si 28.09	15 P 30.97	16 S 32.07	17 Cl 35.45	18 Ar 39.95
19 K 39.10	20 Ca 40.08	21 Sc 44.96	22 Ti 47.87	23 V 50.94	24 Cr 52.00	25 Mn 54.94	26 Fe 55.85	27 Co 58.93	28 Ni 58.69	29 Cu 63.55	30 Zn 65.38	31 Ga 69.72	32 Ge 72.64	33 As 74.92	34 Se 78.96	35 Br 79.90	36 Kr 83.80
37 Rb 85.47	38 Sr 87.62	39 Y 88.91	40 Zr 91.22	41 Nb 92.91	42 Mo 95.94	43 Tc (98)	44 Ru 101.07	45 Rh 102.91	46 Pd 106.42	47 Ag 107.87	48 Cd 112.41	49 In 114.82	50 Sn 118.71	51 Sb 121.76	52 Te 127.60	53 I 126.90	54 Xe 131.29
55 Cs 132.91	56 Ba 137.33	57 La 138.91	72 Hf 178.49	73 Ta 180.95	74 W 183.84	75 Re 186.21	76 Os 190.23	77 Ir 192.22	78 Pt 195.08	79 Au 196.97	80 Hg 200.59	81 Tl 204.38	82 Pb 207.20	83 Bi 208.98	84 Po (209)	85 At (210)	86 Rn (222)
87 Fr (223)	88 Ra (226)	89 Ac (227)	104 Rf (267)	105 Db (268)	106 Sg (269)	107 Bh (270)	108 Hs (270)	109 Mt (278)	110 Ds (281)	111 Rg (282)	112 Cn (285)	113 Nh (286)	114 Fl (289)	115 Mc (290)	116 Lv (293)	117 Ts (294)	118 Og (294)

58 Ce 140.12	59 Pr 140.91	60 Nd 144.24	61 Pm (145)	62 Sm 150.36	63 Eu 151.96	64 Gd 157.25	65 Tb 158.93	66 Dy 162.50	67 Ho 164.93	68 Er 167.26	69 Tm 168.93	70 Yb 173.04	71 Lu 174.97
90 Th 232.04	91 Pa 231.04	92 U 238.03	93 Np (237)	94 Pu (244)	95 Am (243)	96 Cm (247)	97 Bk (247)	98 Cf (251)	99 Es (252)	100 Fm (257)	101 Md (258)	102 No (259)	103 Lr (266)

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.

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1. 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. Ethanol

b. Methane

c. They are equally efficient in kJ/g.

d. MTBE

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)

---

2. 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.

---

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

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

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

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

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

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

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.

---

4. Which of the following is an exothermic process?

a. Boiling water

●b. Freezing water

c. Heating water

d. Melting ice

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

---

5. 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. 83 kJ

● b. 324 kJ

c. 361 kJ

d. 298 kJ

e. 41 kJ

Explanation: Three calculations are necessary here:

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

$q_2 = (125$ g$)(2260$ J/g$) = 282500$ J

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

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

---

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

a. Energy only

● b. Both matter and energy

c. Matter only

d. Neither matter nor energy

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

---

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

a. freezing

● b. sublimation

c. condensation

d. deposition

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.

---

8. 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. exothermic, endothermic, negative, positive

b. endothermic, exothermic, negative, positive

c. exothermic, endothermic, positive, negative

● d. endothermic, exothermic, positive, negative

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

---

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

a. ethanol

● b. wood

c. methane

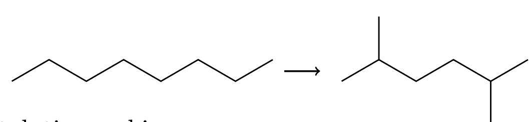
d. propane

e. hydrogen

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

---

10. 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. catalytic cracking

b. fractional distillation

● c. catalytic reforming

d. thermal cracking

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

---

11. The first law of thermodynamics is all about the ______ .

a. dispersal of energy

b. generation of antimatter

●c. conservation of energy

d. conversion of mass to energy

Explanation: conservation of energy

---

12. 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.

---

13. 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. −7.11 kJ

b. +3.92 kJ

c. −5.81 kJ

●d. +7.11 kJ

e. +5.81 kJ

f. −3.92 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.

---

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

a. −1449 kJ/mol

b. −312 kJ/mol

c. −1705 kJ/mol

d. −1300 kJ/mol

●e. −1216 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

---

15. 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. titanium

●b. chromium

c. water

d. air

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

---

16. 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. 715 kJ

●b. 597 kJ

c. 519 kJ

d. 469 kJ

e. 686 kJ

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

---

17. 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. +48.4 kJ/g

b. −39.7 kJ/g

c. −52.9 kJ/g

d. −45.2 kJ/g

e. +55.1 kJ/g

●f. −35.5 kJ/g

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

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

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

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

---

18. 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. 29.8 ° C

b. 8.50° C

c. 21.8.° C

●d. 19.2° C

e. 16.4° C

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

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

$T_f = 19.2$ °C

---

19. When a hydrocarbon for a combustion engine is more branched ______ .

a. it will fail to combust

b. it will have a much higher energy of combustion

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

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

---

20. 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 middle

b. equally dispersed throughout the distillation tower

c. the bottom

●d. the top

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

---

21. 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, III, and IV

b. II and IV

c. I, II, III, and IV

d. I, III, and IV

● e. I 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.

---

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

a. it's time to make the meth

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

c. it's time to build bigger hydrocarbons from 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

---

23. 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. combustion

b. calorimetry

c. catalytic reforming

d. fracking

● e. catalytic cracking

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

---

24. 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. 555 kJ

b. 612 kJ

c. 247 kJ

d. 987 kJ

e. 740 kJ

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

---

25. 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.

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

* * * Remember your Version Number * * *